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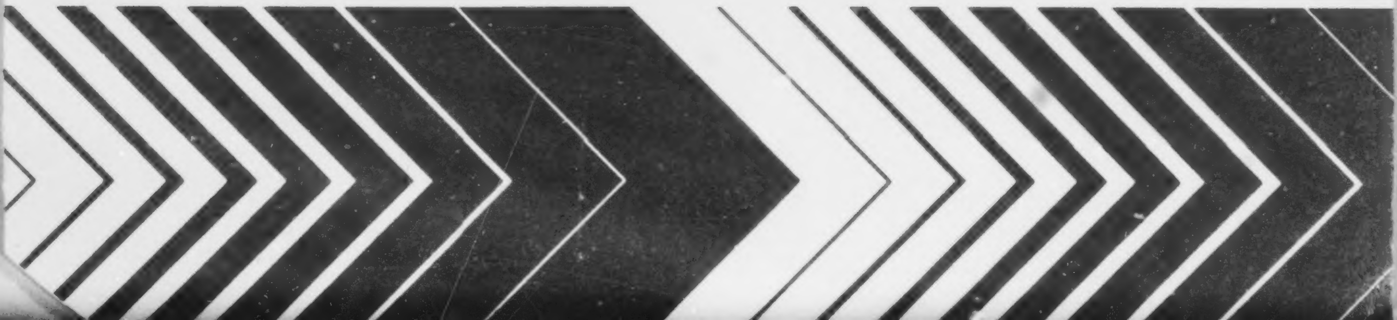

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Titles of 886 technical articles are listed on the subject of toxicological, physiological and metabolic effects of stable and radio-labelled chemical species of metals and metalloids to marine, estuarine, and freshwater flora and fauna. Each reference is annotated and subsequently indexed by metal, by taxa, and by author.

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FOURTH ANNOTATED BIBLIOGRAPHY ON BIOLOGICAL EFFECTS OF METALS IN AQUATIC ENVIRONMENTS

(No. 2247-3132)

by

Ronald Eisler, Richard M. Rossoll,
and Gloria A. Gaboury
Office of Health and Ecological Effects
Environmental Research Laboratory
Narragansett, Rhode Island 02882

ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
NARRAGANSETT, RHODE ISLAND 02882

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FOREWORD

The Environmental Research Laboratory of the U.S. Environmental Protection Agency is located on the shore of Narragansett Bay, Rhode Island. In order to assure the protection of marine resources, the laboratory is charged with providing a scientifically sound basis for Agency decisions on the environmental safety of various uses of marine systems. To a great extent, this requires research on the tolerance of marine organisms and their life stages as well as of ecosystems to many forms of pollution stress. In addition, a knowledge of pollutant transport and fate is needed.

This account lists 886 titles of selected articles from the available technical literature on the subject of toxicological and physiological effects of toxic cations and heavy metals to aquatic biota. Each article is annotated at length, and cross-indexed by metal, by taxon, and by author. It is part of a continuing effort by this laboratory to construct a meaningful platform for use in future research in this area, and for providing a sound data base in updating of existing water quality criteria for metals in freshwater and marine environments.

Donald K. Phelps
Acting Director

ABSTRACT

Titles of 886 technical articles are listed on the subject of toxicological, physiological and metabolic effects of stable and radiolabelled chemical species of metal cations to marine, estuarine and freshwater flora and fauna. Almost all of these articles were published in the two-year period 1977-1978. Each reference was annotated at length and subsequently indexed by metal, by taxa, and by author. The first three volumes in this series, published as U.S. Environmental Protection Agency Reports R3-73-007, 600/3-75-008, and 600/3-78-005, respectively, are available from the National Technical Information Service, Springfield, Virginia 22161.

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SECTION I

INTRODUCTION

As was true in the three preceding volumes in this series*, the present account lists journal articles and reports resulting from laboratory and field investigations on toxicological, physiological and metabolic effects of stable and radioactive species of heavy metals and other cations to aquatic life. Almost all of the references annotated in this fourth volume were published within the two year period 1977-1978, but some have been in print for some time and have only recently become available to us. For this issue we selected articles which emphasized the following response parameters: survival; growth; reproduction; behavior; bioaccumulation; retention; translocation; histopathology; baseline data on elemental composition; changes in exogenous salt content on responses including internal changes in salt balance of body fluids and tissues; interaction effects of metals and their salts in combination with other substances; and finally, modifying effects of biotic and abiotic factors on all parameters examined.

As more information becomes available, and future volumes in this series are produced, it is hoped that contamination standards for each metal can be established administratively at levels which neither jeopardize the stability of aquatic ecosystems nor present a public health hazard via aquatic food chains.

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*Eisler, R. 1973. Annotated bibliography on biological effects of metals in aquatic environments (No. 1-567). U.S. Environmental Protection Agency Report R3-73-007:287 pp. Available from U.S. Department of Commerce, National Technical Information Service, Springfield, Virginia 22161, as Order No. PB-228-211 at a current price of $11.00.

Eisler, R. and M. Wapner. 1975. Second annotated bibliography on biological effects of metals in aquatic environments (No. 568-1292). U.S. Environmental Protection Agency Report 600/3-75-008:400pp. Available from U.S. Department of Commerce, National Technical Information Service, Springfield, Virginia 22161, as Order No. PB-248-211 at a current price of $13.25.

Eisler, R., D.J. O'Neill, Jr., and G.W. Thompson. 1978. Third annotated bibliography on biological effects of metals in aquatic environments (No. 1293-2246). U.S. Environmental Protection Agency Report 600/3-78-005:487 pp. Available from U.S. Department of Commerce, National Technical Information Service, Springfield, Virginia 22161, as Order No. PB-280-953 at a current price of $15.00.

SECTION II

REFERENCES

Each reference is numbered and subsequently indexed by metal(s), by taxonomic group(s) and by author(s) in the INDEX SECTION Section III. Copies of all articles cited in this volume, as well as the first three volumes in this series, are on file with the Librarian, U.S. Environmental Protection Agency, Environmental Research Laboratory, Narragansett, RI 02882, and available for consultation at that location.

2247. Abbott, O.J. 1977. The toxicity of ammonium molybdate to marine invertebrates. Marine Poll. Bull. 8:204-205.

Toxicity of ammonium molybdate, a constituent of some industrial wastes, to hermit crab *Eupagurus bernhardus*, crab *Carcinus maenas*, clam *Venerupis pullastra*, and starfish *Asterias rubens* was investigated under conditions of 12-21 C and 23.5-33.2 o/oo S. The LC-50 (48 hr) value for *Carcinus* was >254 mg Mo/l in pH 7.0, and 1018 in pH about 5.0. The LC-50 (24 hr) for *Eupagurus* ranged between 127 and 254 mg Mo/l in pH 5.1-7.3; LC-50 (48 hr) values varied between 191 and 254 mg/l in pH 7.0-7.8. The LC-50 (24 hr) value for *Asterias* was between 127-254 mg Mo/l in pH 5.1-8.2 and between 254-509 mg/l in pH 5.1-6.2 for *Venerupis*. A 50 day chronic experiment of 100 mg Mo/l produced no mortality in *Eupagurus*. It was concluded that even where hydrolysis produced a reduced pH, which possibly facilitates toxicity in acute tests, ammonium molybdate was comparatively nontoxic to marine invertebrates.

2248. Abernathy, A.R. and P.M. Cumbie. 1977. Mercury accumulation by largemouth bass (*Micropterus salmoides*) in recently impounded reservoirs. Bull. Environ. Contamin. Toxicol. 17:595-602.

Mercury concentrations in axial muscle of bass from South Carolina in 1973 and 1974 ranged from 0.38 to 0.68 mg/kg wet wt in Lake Harwell, 0.34 to 3.99 in Lake Keowee, and 1.89 to 4.49 in Lake Jocassee. Levels generally increased as size class of fish increased from <230 to >380 mm. In 1974, Hg concentration in axial muscle of 231-340 mm bass from Lake Jocassee was 1.9 mg/kg wet wt; in 1975, levels averaged 0.69. In Lake Jocassee, water Hg levels were <0.01 to 0.06 ug/l, and sediment Hg levels were 0.03 to 0.04 mg/kg dry wt. In tributaries entering the lake, Hg concentrations were <0.1 to 0.12 ug/l in water, 0.01 to 0.05 mg/kg dry wt in sediment, and 1.3 to 14.0 mg/kg dry wt in suspended sediment load. Authors suggest that elevated Hg levels in fish are a transitory phenomenon in newly impounded reservoirs, and decline as reservoirs age. Source of Hg appears to be soil which formed the original reservoir sediments.

2249. Al-Daham, N.K. and M.N. Bhatti. 1977. Salinity tolerance of *Gambusia affinis* (Baird & Girard) and *Heteropneustes fossilis* (Bloch). Jour. Fish Biology 11:309-313.

Two species of freshwater teleosts exposed to concentrations of seawater and sodium chloride, calcium chloride, and potassium chloride showed a high tolerance to seawater and NaCl, and low tolerance to KCl. Sodium chloride at 10,000 mg/l had no effect on either species. In 15,000 mg NaCl/l, 75% of *Gambusia* died by 144 hrs; all *Gambusia* died at 72 hrs in 20,000 mg/l. For *Heteropneustes*, all were dead in 48 hrs at 15,000 mg/l NaCl, or 8 hrs in 20,000 mg/l. No *Gambusia* died in 25% SW; 10% died by 144 hrs in 50% SW; and all died by 24 hrs in 75% SW. After 144 hrs, 25% of *Heteropneutes* in 25% SW were dead; all died by 24 hrs in 50% SW or 8 hrs in 75% SW. In $CaCl_2$ for 144 hrs, 10% of the *Gambusia* died in 5,000 mg/l and 83% in 10,000 mg/l; all were dead in 24 hrs at 15,000 mg/l $CaCl_2$. For *Heteropneustes*, 70% died after 144 hrs in 5,000 mg/l $CaCl_2$; all were dead by 24 hrs in 10,000 and by 8 hrs in 15,000 mg/l. Total mortality was seen at 48 hrs in 5,000 and 10,000 mg KCl/l and at 8 hrs in 15,000 mg/l for *Gambusia*, and at 72 hrs, 24 hrs, and 8 hrs with increasing KCl for *Heteropneustes*. In all cases, *Gambusia* were more resistant to salt concentrations than *Heteropneustes*.

2250. Anderson, R.V. 1977. Concentration of cadmium, copper, lead, and zinc in thirty-five genera of freshwater macroinvertebrates from the Fox River, Illinois and Wisconsin. Bull. Environ. Contamin. Toxicol. 18:345-349.

Nineteen species of aquatic insects contained from <0.5 to 6.3 mg cadmium/kg dry wt, <1.0 to 74.2 copper, <4.0 to 39.5 lead, and 75.5 to 270.8 zinc. Five species of crustaceans contained <0.5 to 2.8 mg Cd/kg dry wt, 70.7 to 99.2 Cu, <4.0 to 25.7 Pb, and 64.7 to 124.9 Zn. Ten species of molluscs contained from 1.4 to 3.0 mg Cd/kg dry wt, 5.2 to 22.0 Cu, 10.2 to 32.0 Pb, and 3.7 to 353.0 Zn. Two species of hirudinean annelids had from <0.5 to 3.8 mg Cd/kg dry wt, 7.6 to 16.8 Cu, <4.0 to 39.8 Pb, and 136.2 to 148.4 Zn. There was a wide range of values with individual taxa, but the general pattern was Cd < Cu ≤ Pb < Zn, except in crustaceans where it was Cd < Pb < Cu ≤ Zn. High Cu concentrations in crustaceans is believed to be due to Cu pigment in hemocyanin. Zinc was especially high in most bivalve molluscs, gastropods and several species of insects, and this may reflect a physiological need for Zn.

2251. Anderson, R.V. 1977. Concentration of cadmium, copper, lead, and zinc in six species of freshwater clams. Bull. Environ. Contamin. Toxicol. 18:492-496.

Concentrations of Cd, Cu, Pb, and Zn were determined in Lampsilis siliquoidea, L. ventricosa, Strophitis rugosus, Sphaerium sp., Anodonta marginata, and Lasmigona complanata from Fox River, Illinois and Wisconsin. Shells of the six clams had concentrations of 1.2 to 3.7 mg/kg dry wt of Cd, 3.4 to 10.9 of Cu, 9.2 to 33.0 of Pb, and 3.7 to 11.7 of Zn. Body levels in L. siliquoidea, L. ventricosa, S. rugosus, and Sphaerium sp. ranged from 2.5 to 5.9 mg/kg dry wt for Cd, 7.4 to 22.4 for Cu, 17.6 to 48.2 for Pb, and 130.0 to 319.9 for Zn. In A. marginata and L. complanata, concentrations in muscle, gills, and viscera ranged from 0.4 to 4.8 mg/kg dry wt for Cd, 2.2 to 12.9 for Cu, 1.9 to 24.9 for Pb, and 22.1 to 420.7 for Zn. In only two instances, Cd for Sphaerium sp. and L. complanata, were shell levels higher than body levels for a metal. With the exeption of high Zn values, metal levels in the bodies reflected sediment concentrations.

2252. Andrew, R.W., K.E. Biesinger, and G.E. Glass. 1977. Effects of inorganic complexing on the toxicity of copper to Daphnia magna. Water Research 11:309-315.

Effects of carbonate-bicarbonate, orthophosphate, and pyrophosphate on copper toxicity, at concentrations up to 0.127 mg Cu/l, to Daphnia were studied at constant pH and total hardness. Mortality rates and reciprocal survival times were directly correlated with Cu^{2+} and copper hydroxy ion $[Cu(OH)n]$ activities as determined by equilibrium calculations. Toxicity was negatively related to activities of soluble $CuCO_3$ and other complexes, and independent of dissolved Cu or total Cu concentrations.

2253. Atchison, G.J. 1975. Uptake and distribution of trace metals in fish. Office of Water Resources Research Project No. A-038-IND. Technical Report No. 73. Purdue Univ. Water Res. Res. Cent., West Lafayette, Indiana: 21 pp.

Bluegill Lepomis macrochirus, largemouth bass Micropterus salmoides, and golden shiners Notemigonus crysoleucas, from Palestine Lake, Indiana, the recipient of wastes from a metal plating shop, were analyzed for cadmium and chromium in 1975. Muscle from bluegill and bass contained 0.08 to 3.7 mg Cd/kg dry wt, with a high of 16.0 mg/kg, and 0.04 to 8.4 mg Cr/kg dry wt. In gill tissue values were 0.1 to 6.9 for Cd and 0.5 to 15.0 for Cr; in liver 1.0 to 33.4 for Cd and 0.3 to 45.0 for Cr; and in gastrointestinal tract 0.10 to 51.6 for Cd and 0.2 to 75.5 for Cr. Whole body concentrations in shiners were 0.68 to 0.79 mg Cd/kg dry wt and 2.5 to 3.7 mg Cr/kg dry wt. Water from Palestine Lake contained 0.03 to 0.05 mg Cd/l and 0.005 to 0.01 mg Cr/l near the waste water entrance, and 0.001 to 0.002 mg Cd/l and 0.001 to 0.009 Cr/l in other areas. Sediments near the waste entrance contained 640 to 1300 mg Cd/kg dry wt and 2080 to 3830 mg Cr/kg dry wt; elsewhere in the lake these values ranged from 6 to 200 mg Cd/kg and 90 to 1000 mg Cr/kg.

2254. Badsha, K.S. and M. Sainsbury. 1977. Uptake of zinc, lead and cadmium by young whiting in the Severn Estuary. Marine Poll. Bull. 8:164-166.

First year whitings, Merlangus merlangus, from cooling water intakes of Oldbury Nuclear Power Station, Severn Estuary, England, had maximum levels of zinc in November 1975 and maximum lead and cadmium in March 1976. Metal concentrations from Nov. 1975 to Mar. 1976 ranged from 72.5 to 102.4 mg Zn/kg dry wt, 16.7 to 21.2 mg Pb/kg, and 1.9 to 2.5 mg Cd/kg. These levels were linearly related to both length and weight of fish, positively with Pb and Cd, but negatively with Zn. It was suggested that Zn concentrations reached an upper threshold limit with no further accumulation; this was quickly attained as fish moved into polluted areas.

2255. Bagnyuk, V.M., T.L. Oleynik, N.R. L'vovskaya and L.O. Eynor. 1976. Extraction of iron from water by Chlorella vulgaris and Scenedesmus quadricauda. Hydrobiological Jour. 12:35-41.

Freshwater chlorococcol algae Chlorella and Scenedesmus accumulated large quanitites of iron from water containing 1.0 to 370.0 mg Fe/l. Biological Fe utilization follows two pathways: uptake of Fe ions by algal cells; and precipitation as iron hydroxide owing to increases in pH and oxygen of the medium. In the presence of mixed algal-bacterial cultures, Fe is oxidized in water, with initial pH 5.5. Uptake of Fe by algae is a direct function of iron concentration in culture medium. Utilization of Fe by algal cells alters the ratio of hydrolyzed to non-hydrolyzed forms in cells with 80-90% of the Fe accumulated converted to a non-hemin form. Authors suggest that ability of algae to promote Fe oxidation, followed by precipitation as hydroxide, plus ability to accumulate iron in large quantities can be used in metallurgical plants for biological removal of iron from effluents.

2256. Bakunov, N.A. and S.N. Garanina. 1976. Accumulation of ^{90}Sr and ^{137}Cs by marine and freshwater fish of the Caspian Basin. Soviet Jour. Ecology 7(4):350-353.

Radionuclide levels were determined in 10 species of freshwater teleosts: crucian carp *Carassius carassius*, bream *Abramis brama*, perch *Perca fluviatilus*, pike perch *Lucioperca lucioperca*, northern pike *Esox lucius*, tench *Tinca tinca*, asp *Aspius aspius*, rudd *Scardinius erythrophthalmus*, ide *Leuciscus idus*, carp *Cyprinus carpio*; 5 species of anadromous teleosts during freshwater migration phase: Caspian roach *Rutilus rutilus*, kutum *R. frisii*, black-spined shad *Caspialosa kessleri*, Caspian shad *C. caspia*; and two marine species: sprats *Clupeonella engrauliformis*, *C. grimmi*. In the Volga and Ural Deltas in 1969, 1971, and 1972, the maximum Sr-90 concentrations in freshwater fishes, in mCi/kg wet wt x 10^{-9} were 151 in carp, 146 in black-spined shad, and 102 in ide. Maximum Cs-137 levels were 55 to 71 x 10^{-9} mCi/kg wet wt in pike perch and 62 x 10^{-9} in asp. Black-spined shad, ide, and crucian carp had Sr-90/Cs-137 values of 12.2, 11.3 and 6.7 respectively; for all other species this ratio was <4.0. Maximum concentrations of Sr-90 in marine fishes from the Caspian Sea in 1972 were 36 x 10^{-9} mCi/kg wet wt in carp and 33 x 10^{-9} in *R. frisii*. Cs-137 was highest in shad at 156 x 10^{-9} mCi/kg wet wt. *R. frisii* and carp had Sr-90/Cs-137 values of 1.7 and 1.4, respectively; the rest were <1.0. The relationship between type of nutrition and radionuclide level is discussed.

2257. Banus, M.D. 1977. Copper, iron, and manganese content of mangrove seedlings from Puerto Rico. *In*: Drucker, H. and R.E. Wildung (eds.). Biological implications of metals in the environment. ERDA Symp. Ser. 42:380-389. Avail. as CONF-750929 from

Nat. Tech. Inf. Serv., U.S. Dept. Comm. Springfield, VA 22161.

Seedlings of red mangroves, *Rhizophora mangle* from 6 locations in Puerto Rico with varying amounts of chemical pollution, were analyzed for iron, manganese, and copper. Copper concentrations of seedlings from unimpacted areas were 2.3 to 3.5 mg/kg dry wt, with no difference between leafing (top) and rooting (bottom). In locations subjected to thermal, air, and chemical pollution, sewage, and agricultural runoff, concentrations ranged from 4.1 to 7.2 mg Cu/kg. Iron levels were 8.6 to 25.0 mg/kg dry wt in tops and 11.3 to 22.7 in bottoms from all sites. Estuarine mangroves in unpolluted areas contained 30.0 to 42.6 mg Mn/kg dry wt in tops and 10.2 to 11.0 in bottoms; seedlings from an offshore island had 10.3 mg Mn/kg in tops and 3.7 in bottoms. From polluted areas, Mn levels ranged from 27.0 to 80.0 mg/kg dry wt in tops and 7.4 to 18.9 in bottoms. Top to bottom Mn ratios were 2.7 to 4.2 for seedlings from all areas.

2258. Barlow, D.J. and W.S.G. Morgan. 1975. Energy dispersive X-ray analysis (EDAX) as an autopsy technique for copper-caused fish mortality. Water SA 1(3):109-112.

Energy dispersive analysis of X-rays (EDAX) was used to indicate copper toxicity in the freshwater fish *Sarotherodon mossambicus* after exposure to 5, 10, and 20 mg/l copper sulphate. Copper absorption, relative to calcium content in liver, gill and operculum after exposure to 5 mg Cu/l (control), respectively was: 0.027 (0.007) in liver; 0.009 (0) in gill; and 0.0022 (0) in operculum. For the 10 mg Cu/l group the Cu/Ca ratios were: 0.019 for liver; 0.021 for gill; and 0.0002 for operculum. Fish exposed to 20 mg Cu/l exhibited Cu/Ca ratios of 0.019 for liver; 0.021 for gill; and 0.0003 for operculum. Mean death time of fish exposed to 5 mg Cu/l was 384 min; and for fish in 20 mg Cu/l 91 min. Copper, as a cause of mortality could be detected up to 48 hrs after death. It is probable that the technique is not specific for copper toxicity but could be used for other metal toxicants in dead fish including phosphorus, lead, iron and zinc.

2259. Barnes, D.J. and C.J. Crossland. 1977. Coral calcification: sources of error in radioisotope techniques. Marine Biology 42:119-129.

Isotopic exchange occurs between coral skeleton Ca-45 and HC-14 O_3^- in seawater. Exchange of C-14 onto skeletons is more rapid than exchange of Ca-45. Exchange of C-14 from skeletons to seawater takes place more slowly than exchange of Ca-45 to seawater. An increase in temperature increases percent of radioactivity exchanged onto skeleton. When *Acropora acuminata* is incubated in the dark with Ca-45 Cl_2, NaHC-14 O_3, and C-14 urea for 1 hr, tissues contained more radioactivity than is associated with skeleton. Tissue radioactivity reflects permeation of tissues and coelenteron by radioactive compounds from the incubation seawater. Specimens preincubated with 5mM $ZnCl_2$ and other metabolic inhibitors incorporate more Ca-45 but less C-14 than specimens in filtered seawater. Addition of alkali, KOH, and two brands of domestic bleach, to radioactive seawater results in a radioactive precipitate, part of which becomes associated with any coral skeleton present, and part of which forms on the wall of the containing vessel. Strong alkali removes biologically-deposited radioisotope from coral skeletons. Deposition of C-14 from HC-14 O_3^- in skeletons of living coral incubated in the dark is greater than in dead coral. The reverse situation occurs with Ca-45.

2260. Basiouny, F.M., L.A. Garrard, and W.T. Haller. 1977. Absorption of iron and growth of *Hydrilla verticillata* (L.f.) Royle. Aquatic Botany 3:349-356.

Tissue levels of iron and chlorophyll in *Hydrilla* plants increased as FeEDTA levels in the nutrient solution increased from 0 to 6.0-8.0 mg/l; however, plant values decreased in water containing 8.0 to 15.0 mg Fe/l. Maximum tissue Fe concentration was 22,000 mg/kg wet wt after 7 weeks in 6.0 mg Fe/l solution; *Hydrilla* absorbed and accumulated more Fe than was required for optimum growth; growth was greatest in 8.0 mg Fe/l solutions. Manganese concentrations decreased from 450 to 150 mg/kg wet wt as Fe content in solution increased from 0.0 to 15.0 mg/l. Best growth and highest dry weight of *Hydrilla* were obtained at a comparatively high Fe/Mn ratio of 85.

2261. Baudin, J.-P. 1974. Premières données sur l'étude expérimentale du cycle du zinc dans l'étang de l'Olivier. Vie Milieu 24(1) Ser. B:59-80.

Zinc-65 transfer from marine lagoon waters to sediments at 5, 15 and 25 C was measured over a period of 48 days; sediment Zn-65 levels were highest at 25 C and lowest at 5 C. *Cladophora* sp. of algae concentrated radiozinc from the medium by factors of 540 (initial Zn-65 in medium 995 d/m/ml, 12 day study, 5 C), 3647 (initial Zn-65 530 d/m/ml, 34 day study, 5 C), 1350 (910 d/m/ml, 12 days, 15 C), 4680 (475 d/m/ml, 34 d, 15 C), 1785 (865 d/m/ml, 12 d, 25 C) and 4212 (485 d/m/ml, 34 d, 25 C). Data are also presented on elimination rates. Radiozinc transfer through a food chain from labelled *Cladophora* to a gastropod *Physa acuta*, and from *Cladophora* to an isopod *Sphaeroma hookeri*, was also determined. For both predator species, accumulation was most rapid during the first 10 days of a 30 day study.

2262. Bayley, I.L. and E.A. Freeman. 1977. Seasonal variation of selected cations in *Acorus calamus* L. Aquatic Botany 3:65-84.

Seasonal differences in K, Ca, Mg, Mn and Na were studied for the freshwater emergent macrophyte, *Acorus calamus*, collected from a flood plain in Ontario, Canada. A moderate to high correlation was found between time of year and magnesium and manganese concentrations in above ground organs; concentrations ranged from 2,200 mg Mg/kg dry wt in June to 800 in August; and from 140 mg Mn/kg dry wt in June to 20 in September. Both Mg and Mn in underground organs were poorly correlated with season: for Mg, values ranged from 600 mg/kg dry wt in June to 120 in September; for Mn, it ranged from 160 mg/kg dry wt in June to almost zero in September. Calcium concentration in above ground organs ranged, in mg/kg dry wt, from 13,000 in September to 300 in July; subsurface organ values were 800 in June, to 300 in October (the latter showed a moderate correlation between time of year in both above and underground organs). Potassium values in above ground organs ranged from 48,000 mg/kg dry wt in June to 800 in October; for sodium in underground organs these were 800 mg/kg dry wt in June to 150 in September.

2263. Bebbington, G.N., N.J. Mackay, R. Chvojka, R.J. Williams, A. Dunn and E.H. Auty. 1977. Heavy metals, selenium and arsenic in nine species of Australian commercial fish. Austral. Jour. Marine Freshwater Res. 28:277-286.

Mean metal levels in nine species of important commercial fish from New South Wales waters were: 0.03 to 0.38 mg/kg wet wt for mercury, mainly as methyl Hg, 0.04 for cadmium, 0.04 to 0.87 for copper, 0.4 to 0.7 for lead, 4.2 to 9.6 for zinc, 0.2 to 2.2 for arsenic, and 0.2 to 0.5 for selenium. All except one of the 232 fish analyzed had metal concentrations below the National Health and Medical Research Council (NHMRC) standards of 2.0 mg/kg wet wt for Cd, 30.0 for Cu, 2.0 for Pb, 2.0 for Se, and 1000 for Zn. Specimens of bream *Acanthopagrus australis*, snapper *Chrysophrys auratus*, mulloway *Sciaena antarctica*, kingfish *Seriola grandis*, Australian salmon *Arripis trutta*, and yellowfin tuna *Thunnus albacares*, accounting for 7% of the total sample, had Hg concentrations in excess of the NHMRC standard of 0.5 mg/kg wet wt. No sea mullets *Mugil cephalus*, flatheads *Platycephalus fuscus*, or tailors *Pomatomous saltatrix*, exceeded this limit. Twenty-one percent of 95 fish analyzed had As concentrations equal to or greater than the standard of 1.14 mg/kg. Health risks associated with Hg and As in these species are discussed.

2264. Beckett, J.S. and H.C. Freeman. 1974. Mercury in swordfish and other pelagic species from the western Atlantic Ocean. *In*: U.S. Dept. Commerce, NOAA Spec. Sci. Rept. (Fisheries) No. 675:154-159.

Mean mercury content in dorsal muscle of 16 species of fishes and elasmobranchs, in mg/kg wet wt were: swordfish *X. gladius* 1.15; bluefin tuna *Thunnus thynnus* 0.80; white marlin *Tetrapturus albidus* 1.34; escolar *Lepidocybium flavobrunneum* 0.62; dolphin *Coryphaena hippurus* 0.86; long nose lancetfish *Alepisaurus ferox* 0.08; blue shark *Prionace glauca* 0.70; sickle shark *Carcharhinus falciformis* 1.43; dusky shark *C. obscurus* 2.08; tiger shark *Galeocerdo cuvieri* 0.83; hammerhead shark *Sphyrna lewini* 3.64; mako shark *Isurus oxyrinchus* 1.16; porbeagle shark *Lamna nasus* 0.55; mackerel shark 2.08; white shark *Carcharodon carcharias* 18.85; and basking shark *Cetorhinus maximus* 0.08. Total mercury content in food species taken from stomachs of swordfish in mg/kg wet wt were: butterfish Centrolophus niger 0.14; scaled dragonfishes Stomias boa 0.17; lanternfishes 0.24; barracudinas 0.20; lancetfishes Alepisaurus ferox 0.41; snipe eels Nemichthys scolopaceus 0.24; cods Merluccius bilinearis 0.17; jacks 0.13; mackerel Scomber scombrus 0.17; scorpion fishes Sebastes marinus 0.34; filefishes 0.21 and squids Ilex illecebrosus 0.31. Total mercury content of selected swordfish tissues in mg/kg wet wt were: red muscle 1.59; abdominal muscle 1.10; liver 3.00; kidney 1.91; heart 1.64; brain 0.90; gill 0.43; vertebral disc 0.20; and stomach 0.50. Mercury levels were related to fish size with larger fish having higher levels, but the relationship varied with time and area of capture. Males tended to have higher levels than females.

2265. Bedford, J.J. and J.P. Leader. 1977. The composition of the haemolymph and muscle tissue of the shore crab, Hemigrapsus edwardsi, exposed to different salinities. Comp. Biochem. Physiol. 57A:341-345.

Hemigrapsus is a typical euryhaline poikilosmotic animal. External medium changes produce corresponding though lesser changes in haemolymph composition over the crab's survival range of 25% to 110% seawater. Muscle fiber water rose by only 25% over this range, while concentration of NaCl in haemolymph fell by >40%. Amounts of intracellular sodium, chloride, calcium, potassium, and magnesium showed no significant changes although ninhydrin-positive substances (amino acids) amounts fell more than expected by dilution. Authors suggest that the fall in concentration of haemolymph of crabs acclimated to dilute media is balanced intracellularly by a reduction in amount of amino acids.

2266. Beers, J.R., G.L. Stewart, and K.D. Hoskins. 1977. Dynamics of micro-zooplankton populations treated with copper: controlled ecosystem pollution experiment. Bull. Marine Science 27:66-79.

Taxonomic composition, numerical abundance, and biomass of microplankton (including protozoa, phoronids, tunicates, crustaceans, echinoderms, molluscs, annelids, and rotifers) from Saanich Inlet, British Columbia, were monitored in copper concentrations of 0.005, 0.010, and 0.050 mg/l. Differences between experimental and control populations were greatest at 0.050 mg Cu/l, decreasing with lower concentrations. The major ciliate groups dropped out of the contained ecosystem with 0.050 mg Cu/l and did not reappear. Oligotrich ciliates developed in 0.005 and 0.010 mg Cu/l, but with different species than controls. Among important micrometazoan taxa, naupliar copepod abundances were lower relative to controls in 0.050 and 0.010 mg Cu/l, but not in 0.005 mg/l. Observed effects on micro-zooplankton taxa may not be related to direct action of Cu, but may have resulted from modifications to other trophic levels of the contained populations.

2267. Bentley-Mowat, J.A. and S.M. Reid. 1977. Survival of marine phytoplankton in high concentrations of heavy metals, and uptake of copper. Jour. Exp. Mar. Biol. Ecol. 26:249-264.

Growth of *Phaeodactylum tricornutum*, *Tetraselmis* spp., *Dunaliella primolecta* and *Cricosphaera elongata* (*Hymenomonas elongata*) in batch culture was not arrested on addition of copper, cadmium, or lead concentrations below 10^{-4} M. Level of Cu in natural waters around Scotland was 10^{-7} M or less. All groups dropped to <20% yield in 10^{-4} M to 10^{-2} M Pb, 10^{-3} to 10^{-2} M Cu, or 10^{-3} to 10^{-2} M Cd. *Ditylum brightwelli* exhibited osmotic disturbance in 10^{-5} M and 10^{-4} M Cu, with swelling of cell contents. *Phaeodactylum* grown in continuous culture survived single doses of up to 10^{-3} M Cu with no diminution in growth. Maximum Cu uptake was 0.15 mg/kg of culture held between days 7 and 18; this decreased in 10^{-4} M Cu seawater. In 10^{-3} M Cu, algal concentrations peaked at 2.5 mg Cu/kg after 11 days. *Cricosphaera* in continuous culture survived up to 10^{-4} M Cu with no long-term diminution in growth, but accumulated less Cu than *Phaeodactylum*. Maximum uptake in both 10^{-5} and 10^{-4} M Cu was about 0.01 mg/kg at day 2 and 4, respectively.

2268. Best, E.P.H. 1977. Seasonal changes in mineral and organic components of *Ceratophyllum demersum* and *Elodea canadensis*. Aquatic Botany 3:337-348.

Seasonal changes in 1974 and 1975 of some organic and mineral components of the two dominant macrophytes in a sandpit were investigated. Both species occur in the normal vegetative form in summer and the dormant form in winter. Calcium content increased towards winter to 36,000 mg/kg dry wt in Ceratophyllum, and 48,000 in Elodea. Minimum concentrations were 16,000 and 2,300, respectively. Ca in water was lower in summer, 40 mg/l, than in winter, 50-54. Magnesium content of Ceratophyllum ranged from 2500 to 1900 mg/kg dry wt in summer and 4800 to 4900 in winter. In Elodea, accumulated Mg in September was 1300-3500, but almost zero in August; ambient water concentrations fluctuated between 7.7 and 9.0 mg/l. Manganese contents were high in winter, 17,000 mg/kg dry wt in Ceratophyllum and 7800 in Elodea, and decreased to almost zero in June-July; Mn in water was maximal at 0.24 mg/l in winter, and minimal at 0.05 in September. Iron was highest in late summer, and lowest in February 1974 (1300 mg/kg dry wt in Ceratophyllum and 800 in Elodea). Fe in lake waters fluctuated from 0.1 mg/l in January to 0.01-0.03 in August. Carbon, nitrogen, protein, and starch also fluctuated with season.

2269. Betz, M. 1977. Investigations on the simultaneous uptake and release of mercury by Dunaliella tertiolecta. Marine Biology 41:89-97.

Uptake and release of mercury by the marine alga Dunaliella was followed by adding 0.143 mg/l Hg-203 to the culture, then, after washing, reculturing in media containing 0.0, 0.04, 0.10, or 0.22 mg $HgCl_2$/l labelled with Hg-197. After 8 days, only 20% of the original dissolved mercury remained; volatile Hg increased sharply during this period. In culture containing nutrients, maximum amounts of gaseous mercury, increasing with increasing Hg levels of solutions, occurred at the time of highest chlorophyll a content. In absence of nutrients, this trend was not as evident. Chlorophyll a content increased from 0.70 to 1.02 mg/l as Hg levels increased in cultures with nutrients; without nutrients this increase was from 0.58 to 0.65 mg/l. Excretion of Hg was independent of dissolved organic carbon. Although DOC levels among cultures did not change, more organic substances were excreted by nutrient-rich cultures than nutrient-poor cultures. Cultures with nutrients therefore contained less soluble mercury. The ratio of gaseous Hg/dissolved Hg was nearly identical for culture solutions and blanks, showing similar volatility for the dissolved form in all cases. This led to the assumption that the main part of dissolved Hg in culture solutions was in the inorganic state.

2270. Bishop, J.N. and B.P. Neary. 1977. The distribution of mercury in the tissues of freshwater fish. *In*: Drucker, H. and R.E. Wildung (eds.). Biological implications of metals in the environment. ERDA Symp. Ser. 42:452-464. Avail. as CONF-750929 from Nat. Tech. Inf. Serv., U.S. Dept. Comm., Springfield, VA 22161.

Mercury concentrations in muscle of fish from Hg-contaminated areas in Ontario were: 0.46-0.57 mg/kg for carp, 1.04-1.05 for lake trout, 0.76-1.14 for small catfish, 1.43-1.55 for large catfish, 2.18-2.19 for northern pike, and 2.21-2.27 for pickerel. For some benthopelagic species, gradients of increasing Hg content towards internal muscle and the head regions were observed. Lipid content was inversely related to mercury in muscle. Predaceous walleye and northern pike did not show these relationships. Proportions of methylmercury to total mercury did not vary in muscle for any species examined. Nearly all mercury in fish muscle was in methyl form, however, methyl to total Hg ratios were as low as 53% in nonmuscle organs. Generally, skin, scales, and bone had low Hg concentrations compared to muscle; liver and kidney levels were higher. Mercury patterns in organs were examined as an indicator for Hg uptake by fish. Authors concluded that "snip" samples from flesh would not provide the same precision as subsampled fillet homogenates.

2271. Blaxter, J.H.S. 1977. The effect of copper on the eggs and larvae of plaice and herring. Jour. Marine Biol. Assn. U.K. 57:849-858.

Estimated time to 50% mortality (ET-50) for newly-hatched larvae of plaice, *Pleuronectes platessa*, dropped from >24 days in 0.00-0.09 mg Cu/l, to 4-10 days in 0.9 mg/l, and 1.3 days in 2.0 mg/l. Older larvae, aged 31-42 days, showed higher mortality in 0.3 mg Cu/l, with ET-50 of 3.6 to 8.0 days, while controls survived >9 to >21 days. In 0.09 mg Cu/l, ET-50 for 42 day old larvae was 5.6 days. Newly-hatched larvae of herring, *Clupea harengus*, showed an increase in mortality in >2.0 mg Cu/l; ET-50 was <1 day compared with >12 days in 0.0-1.0 mg Cu/l. Herring eggs were more sensitive than larvae, since successful hatching was a low as <10% in 0.003 mg Cu/l. Sublethal effects of copper on feeding of plaice were evident at about 1.0 mg/l in young feeding larvae, and 0.09 mg/l in older larvae and yolk sac plaice. Growth and differentiation were retarded in feeding plaice larvae at 0.09-0.3 mg Cu/l. Activity of herring larvae, as shown by a laboratory-scale vertical migration, was impaired in 0.3 mg Cu/l.

2272. Blinn, D.W., T. Tompkins, and L. Zaleski. 1977. Mercury inhibition on primary productivity using large volume plastic chambers in situ. Jour. Phycology 13:58-61.

Effects of mercury concentrations of <0.02 to 1.25 mg/l on primary production of phytoplankton in Lake Powell, Arizona, was studied in 1974 and 1975. Photosynthetic activity was 75-100% of controls in 0.013 to 0.064 mg Hg/l, and <35% in 0.085 to 1.25 mg/l following 2 or 25 hr exposure. No significant difference was seen with different time periods. Summer phytoplankton assemblages had a toxic Hg threshold of 0.06 mg/l; productivity decreased from about 1,100 mg C/m^2/day to <400. A threshold concentration was absent for the spring assemblage; productivity decreased linearly from 360 to 120 mg C/m^2/day as Hg increased to 0.11 mg/l. Differences between spring and summer phytoplankton populations may suggest subtle differences in Hg sensitivity in combination with temperature acting on total community metabolism.

2273. Borowitzka, L.J. and B.E. Volcani. 1977. Role of silicon in diatom metabolism. Arch. Microbiology 112:147-152.

Levels of cyclic nucleotides, cAMP, and cGMP were monitored in four species of freshwater and marine pennate diatoms, one in silicon-starved and light-dark synchronized cultures. In Si-starved cultures of Cylindrotheca fusiformis, amounts of protein, and to a lesser extent cAMP, increased; cell number, DNA, and cGMP stayed about level. When 12 mg Si/l, as sodium silicate, was added at hour 25, cAMP, cGMP, and DNA levels rose rapidly. cAMP and cGMP declined before DNA synthesis was complete and continued to fall prior to cell separation. In unstarved synchronies, net synthesis of DNA continued until cell separation. One hour before cell separation, cAMP levels fell while those of cGMP rose. Results support the proposal that cAMP and cGMP may play a part in diatom cell division, possibly involving silicon.

2274. Bouquegneau, J.M. 1977. ATPase activity in mercury intoxicated eels. Experientia 33:941-943.

Na^+K^+ATPase activity in gill of eels Anguilla anguilla in seawater as related to total ATPase activity, declined to one-third of control values upon addition of 2.7 mg/l of $HgCl_2$. Activity increased to normal with 1.0 mM cysteine in the mercury mixture. Total ATPase activity decreased 70% in 0.27 mg/l $HgCl_2$, and 50% in 0.67 to 2.7 mg Hg/l. In CH_3HgCl, enzyme activity dropped to 70% in ≈1.3 mg/l and leveled at 50% in from ≈2.6-5.2 mg Hg/l. Ouabain-non sensitive ATPase activity followed a similar trend. Ouabain-sensitive Na^+K^+ATPase activity was unaffected in Hg concentrations from 0.0 to 12.0 mg/l, then decreased as Hg increased to 19.0 mg/l. Concentrations of Na and Cl were steady at approximately 150 meq/l in concentrations of 0.0 to 12.0 mg Hg/l, peaked at 270 (Na) and 230 (Cl) in 18.0 mg Hg/l, and declined slightly in 19.0 mg Hg/l. Imbalance of eel NaCl levels was caused by Hg inhibition of ouabain-sensitive Na^+K^+ATPase activity in gills.

2275. Boyden, C.R. 1977. Effect of size upon metal content of shellfish. Jour. Marine Biol. Assn. U.K. 57:675-714.

Influence of body size upon whole tissue metal content of 13 species of estuarine and marine molluscs was examined for Cd, Cu, Fe, Mn, Ni, Pb, and Zn. Overall, regression slopes fell into two categories: those around 0.77 and those close to 1.00. In the former case, Mytilus edulis had higher zinc concentrations in the smallest individuals; in the second case, cadmium in M. edulis was independent of size. In several cases, such as Cd in Patella vulgata, maximum levels were recorded in the largest specimens. Large Pecten maximus had very high Cd concentrations. Comparison between species populations from clean and contaminated environments indicate that regression slopes could be either constant, such as Zn and probably Cd in Ostrea edulis and Cd and Zn in M. edulis, or variable, such as Cd and Zn in P. vulgata with increase of slopes in metal elevated environments. Large specimens of Crassostrea gigas, Ostrea edulis, and M. edulis required >5 months to equilibrate to exceptionally high environmental Cu concentrations, the same was true for Zn in C. gigas. Steeper slopes, and almost twice as much variability, were recorded when using wet wt data compared with dry wt.

2276. Brkovic-Popovic, I. and M. Popovic. 1977. Effects of heavy metals on survival and respiration rate of tubificid worms: part I-effects on survival. Environ. Poll. 13:65-72.

LC-50 tests for cadmium, copper, mercury, zinc, chromium, and nickel were conducted with Tubifex tubifex in four diluents of different hardness and alkalinity. Types of dilution water ranged in calcium from 0.0 to 94.7 mg/l, in magnesium from 0.0 to 5.93, and in phosphate from 0.0 to 29.6. LC-50 (24 hr) values ranged from 0.12 to 75.8 mg/l for Zn, 0.08 to 86.0 for Cr, 0.12 to 120.0 for Ni, 0.004 to 1.2 for Cd, 0.01 to 1.4 for Cu, and 0.08 to 0.11 for Hg. LC-50 (48 hr) values were 0.11 to 60.2 mg/l for Zn, 0.06 to 4.6 for Cr, 0.08 to 61.4 for Ni, 0.003 to 0.72 for Cd, 0.006 to 0.89 for Cu, and 0.06 to 0.10 for Hg. Increasing alkalinity and hardness of diluent reduced toxicity of metal salts tested; correlation coefficients ranged from 0.94 for Hg to 0.99 for Cu.

2277. Brkovic-Popovic, I. and M. Popovic. 1977. Effects of heavy metals on survival and respiration rate of tubificid worms: part II-effects on respiration rate. Environ. Poll. 13:93-98.

Oxygen consumption of Tubifex tubifex in concentrations of cadmium, chromium, copper, mercury, nickel, and zinc for 6 hours was determined using dilution water for BOD test with phosphate buffer added. Respiration rate increased to 850 ml O_2/kg wet wt from control value of 750, as Cd concentration increased from 0.0001 to 0.01 mg/l, then declined to 650 at the LC-50 (48 hr) value of 0.06 mg Cd/l and 670 at LC-50 (24 hr) value of 0.08 mg Cd/l. Increasing Cu caused a decrease in O_2 consumption, to 630 from control of 750 mg O_2/kg wet wt, as levels increased from 0.001 to 0.7 mg Cu/l. LC-50 (48 hr) and LC-50 (24 hr) values were 0.3 and 1.0 mg Cu/l, respectively. Respiration rate peaked at 850 mg O_2/kg wet wt in 0.01 mg Hg/l, above 750 for controls, then rapidly declined to 560 as Hg increased to 0.8. LC-50 values for 48 hr and 24 hr were approximately 0.1 mg Hg/l. In Zn, maximum respiration rate was 700 mg O_2/kg wet wt at 1.0 mg/l; at 4-5 mg Zn/l, the LC-50 (48 hr) and (24 hr) values, rates dropped to 660, still above control respiration of 630. No effect was shown in 0.01 and 0.1 mg Cr/l; however, oxygen consumption increased to 800 from control of 630 mg O_2/kg wet wt as levels increased to LC-50 (24 hr) value of 10.0 mg Cr/l; LC-50 (48 hr) was 20.0 mg Cr/l. Respiration rate decreased slightly to 770 compared with controls of 800 ml O_2/kg wet wt in 1.0 mg Ni/l, but increased to 1150 at approximately 10 mg/l, the LC-50 (48 hr) value; the LC-50 (24 hr) was 30 mg Ni/l. Authors indicate that alteration of respiration rate may be useful in toxicity evaluation studies.

2278. Brown, B.E. 1977. Uptake of copper and lead by a metal tolerant isopod Asellus meridianus Rac. Freshwater Biology 7:235-244.

The Hayle River contains comparatively high concentrations of copper and trace amounts of lead; the Gannel River is a high-lead environment. A. meridians from sites on both rivers accumulate copper from 0.5 mg Cu/l solutions and lead from 0.5 mg Pb/l solutions. Accumulated Cu concentrations in whole animal after exposure for 8 days ranged from 430 to 1170 mg Cu/kg wet wt over control values; for Pb this was 5280 to 19,920 mg/kg over controls. Tolerant animals also accumulated Cu and Pb from metal-enriched food. Copper-tolerant isopods contained up to 6.8 mg Cu/kg after feeding on a Cu-enriched diet for 12 days; non-tolerant isopods showed no evidence of Cu accumulation from food but all died within 8 days. Lead-tolerant animals accumulated up to 28 mg Pb/kg during exposure for 14 days to a lead diet: non-tolerant animals showed no accumulation of lead from food and all were dead within 10 days. Electron micrographs of the hepatopancreas show Cu-storage forms resembling cuprosomes and granular inclusions bound in spherical vesicles. The discovery of sulphur-metal complexes in Cu and Pb tolerant Asellus from the River Hayle may account, in part, for observed tolerances.

2279. Brown, B.E. 1977. Effects of mine drainage on the River Hayle, Cornwall A) Factors affecting concentrations of copper, zinc and iron in water, sediments and dominant invertebrate fauna. Hydrobiologia 52:221-233.

In water collected from 13 stations on the River Hayle, England, at least 70% of the Cu and Fe was associated with particulate fractions whereas 80% of Zn was in soluble form. Total concentrations of Zn in water were generally 0.4 to 1.2 mg/l with a peak of 2.6. Water Cu levels ranged from 0.1 to 0.2 mg/l, with a maximum of 0.7. In sediments, Cu levels were generally 1000 to 3000 mg/kg with a maximum of 5000, 3X higher than Zn which was always <2000 mg/kg. Iron was the most abundant metal, up to 6.0 mg/l in water and 400,000 mg/kg in sediment. Seasonal differences in total metal content in water increased during periods of high flow and decreased during low flow. Cu levels in sediment, unlike Fe and Zn, showed higher values during summer and minimal flows. Insect larvae contained 45 to 1000 mg Cu/kg dry wt, 65 to 5000 mg Zn/kg, and 260 to 9800 mg Fe/kg. In free living Trichoptera larvae, tissue levels of Cu and Zn seemed to reflect water metal levels. Species of crustaceans, molluscs, annelids, and platyhelmintheds were also found at various sites. Factors affecting animal/metal relationships are discussed with reference to adaptation to high environmental concentrations of heavy metals.

2280. Brown, D.A. 1977. Increases of Cd and the Cd:Zn ratio in the high molecular weight protein pool from apparently normal liver of tumor bearing flounders (Parophrys vetulus). Marine Biology 44:203-209.

Liver of tumor bearing flounders was studied for the role of metallothioneins in binding excess cadmium, copper or zinc. Composite gel elution profiles for nontumor and tumor bearing flounders are presented. Total distribution of Cd, Cu and Zn among protein peaks from liver cytoplasm of nontumor flounders in umole/g tissue wet wt were: 0.0098 Cd, 1.81 Cu, and 0.198 Zn. These values in tumor bearing fish were 0.0198 Cd, 1.85 Cu, and 0.293 Zn. Cadmium and zinc were not increased significantly in tumor bearing fish relative to nontumor bearing fish on the metallothionein peak, but were increased 3.3 and 2.4-fold, respectively, on the high molecular weight protein peak. Overall, there is a 2-fold increase of Cd in tissue homogenate supernatant of the tumor bearing fish. Increases in Cd in liver of tumor bearing fish are greater than those of Zn as indicated by a 40% increase in the Cd:Zn ratio on the high molecular weight protein peak. Copper shows only small inconsistent changes in tumor bearing fish relative to nontumor bearing fish. Author discusses results in terms of competition of Cd and Zn for Zn-requiring enzymes involved in nucleic acid metabolism.

2281. Brown, E.R., T. Sinclair, L. Keith, P. Beamer, J.J. Hazdra, V. Nair, and O. Callaghan. 1977. Chemical pollutants in relation to diseases in fish. In: Kraybill, H.F., C.J. Dawe, J.C. Harshbarger, and R.G.

Tardiff (eds.). Aquatic pollutants and biologic effects with emphasis on neoplasia. Annals N.Y. Acad. Sciences 298:535-546.

Water analysis was made since 1970 for the comparatively polluted Fox River, near Chicago, and the relatively clean Canadian Lake of the Woods. Maximum mineral concentrations, in mg/l, in Fox River were 55.0-58.0 for magnesium, 17.5-45.5 for sodium, and 38.5-45.0 for calcium. High concentrations for the Canadian Lake were 12.5 for Mg and 14.0-16.0 for Na. Also analyzed were Al, As, Sb, Bi, Mn, Hg, Ni, Fe, Pb, Cd, Cu, K, Zn, and other minerals and organic compounds. Frequency of nononcogenic fish diseases was more than 400% higher in polluted Fox River than Lake of the Woods; incidence of oncogenic diseases paralleled but did not match this finding. Mortality of bluegill sunfish populations exposed to 5 mg Cd/l was 100%; for 200 mg Mg/l this was 95%; 5 mg Zn/l killed 84%; 200 mg Ca/l produced 60% dead; and 5 mg As/l killed 80%.

2282. Brown, J.R. and L.Y. Chow. 1977. Heavy metal concentrations in Ontario fish. Bull. Environ. Contamin. Toxicol. 17:190-195.

Concentrations of Cd, Cu, Pb, Hg and Zn were determined in various tissues from 15 species of fish in Baie du Doré, Lake Huron, and in Toronto Harbour, Lake Ontario. Concentrations were similar in the various species studied. Mean concentrations, in mg/kg wet wt, in muscle were 0.06 for cadmium in fish from Baie du Doré and 0.13 Cd from Toronto Harbour, 0.45 and 1.9 for copper, 0.19 and 1.8 for lead, 4.7 and 36.0 for zinc, and 0.06 and 0.24 for mercury, respectively. Liver had values of 0.16 and 0.13 for Cd, 5.2 and 16.4 for Cu, 0.24 and 1.5 for Pb, and 15.1 and 89.0 for Zn, respectively. Concentrations in kidney were 0.40 and 0.42 for Cd, 4.7 and 4.3 for Cu, 1.4 and 6.6 for Pb, and 26.1 and 59.4 for Zn, respectively. Heavy metal concentrations in sediments were <2.5 mg/kg dry wt for Hg and Cd from both areas, 4 from Baie du Doré and 35 from Toronto Harbour for Cu, 6 and 72 for Pb, and 17 and 98 for Zn, respectively. Concentrations of metals in muscle from fish in Toronto Harbour were consistently higher than specimens from Baie du Doré, reflecting sediment concentrations of these elements.

2283. Bryan, G.W. 1976. Heavy metal contamination in the sea. In: Johnston, R. (ed.). Marine Pollution. Academic Press, London:185-302.

Contamination of sediments and marine or marine-related organisms by Ag, Al, As, Be, Ca, Cd, Co, Cr, Cu, Fe, Hg, La, Li, Mg, Mn, Mo, Na, Ni, Pb, Sb, Se, Sn, Ti, Tl, U, V, W, Zn, and Zr is reviewed. Topics discussed include sources of metals, concentrations and fates of metals in seawater and sediments, concentrations, uptake, toxicity and sublethal effects in plants and animals, and effects to man.

2284. Bryan, G.W. and L.G. Hummerstone. 1977. Indicators of heavy-metal contamination in the Looe Estuary (Cornwall) with particular regard to silver and lead. Jour. Marine Biol. Assn. U.K. 57:75-92.

Looe Estuary has two branches, one receiving lead and silver from old mines, and the other receiving silver from presumed industrial sources. Analyses of Ag, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn were made in the seaweed *Fucus* as an indicator of levels in water; in herbivorous gastropods *Littorina littorea* and *Patella vulgata*, and in filter feeding bivalves *Mytilus edulis* and *Cerastoderma edule* as indicators of metals in suspended particles; in deposit feeding bivalves *Scrobicularia plana* and *Macoma balthica* and worm *Nereis diversicolor* as indicators of sediment levels; and in the carnivorous gastropod *Nucella lapillus*. Lead averaged 280 mg/kg dry wt in sediments, a maximum of 189 in *Scrobicularia*, and 34-54 mg/kg dry wt in *Macoma*, *Fucus*, *Nereis*, and *Mytilus*. Pb contamination followed a similar pattern in different species. Mean Ag level in estuarine sediments was 1.5 mg/kg dry wt; maximum averages in animals were 85 mg Ag/kg dry wt in *Macoma* and 40 in *Scrobicularia*. There was little evidence of contamination of dissolved silver in the estuary, but considerable contamination by particles of freshwater origin. Although particulate Ag concentrations were of the same magnitude from both sources, the influence of the non-mining source was much greater; Ag concentrations 425X above normal were found in *Scrobicularia* upstream. It was concluded that particles, perhaps silver sulfide, from the mining source were not as available to organisms as from other sources wherein silver may be adsorbed onto particles.

Average levels of metals in sediments and maximum averages in organisms, in mg/kg dry wt, were: 0.2 and 12.8 in *Nucella*, respectively, for Cd; 11.1 and 8.9 in *Scrobicularia* for Co, 36 and 2.8 in *Scrobicularia* for Cr; 63 and 300 in *Macoma* for Cu; 27,900 and 1640 in *Patella* for Fe; 426 and 363 in *Fucus* for Mn; 34 and 44 in *Cerastoderma* for Ni; and 151 and 974 in *Scrobicularia* for Zn.

2285. Bryan, G.W., G.W. Potts, and G.R. Forster. 1977. Heavy metals in the gastropod mollusc *Haliotis tuberculata* (L.). Jour. Marine Biol. Assn. U.K. 57:379-390.

Concentrations of Ag, Al, Ca, Cd, Co, Cr, Cu, Fe, Mg, Mn, Ni, Pb, and Zn were measured in whole soft parts, foot, viscera and individual tissues of *Haliotis*. Concentrations in whole soft parts in mg/kg dry wt were 2.9 Ag; 65 to 67 Al; 1180 to 1190 Ca; 4.8 to 5.6 Cd; 0.23 to 0.44 Co; 0.82 to 0.88 Cr; 28 to 29 Cu; 306 to 474 Fe; 4210 to 4290 Mg; 2.9 to 3.3 Mn; 13.6 to 15.9 Ni; 2.1 to 2.2 Pb; and 98 to 103 Zn. In viscera, metal concentrations always exceeded those in the foot, sometimes by an order of magnitude. Viscera accounted for about 26% of the dry weight of the soft parts and contained more than 50% of all metals except nickel and 90% or more of cadmium, iron and cobalt. Highest levels of copper were in blood and left kidney. High levels of nickel were associated with surface tissues such as the mantle and epidermis of the foot. The highest concentrations of other metals were in the digestive gland or the right kidney which seems to be functionally different from the left.

2286. Buchardt, B. and P. Fritz. 1978. Strontium uptake in shell aragonite from the freshwater gastropod *Limnaea stagnalis*. Science 199:291-292.

Shell aragonite from *Limnaea stagnalis* grown in laboratory tanks at different temperatures in water with variable Sr/Ca ratios were analyzed for strontium. Within the limits defined by natural freshwater environments, the Sr/Ca ratio in aragonite was linearly related to the Sr/Ca ratio in water. A distribution coefficient was unaffected by variations in temperature and growth rate. This finding substantiates the existence of a strontium-discriminating effect in aragonite precipitated by mollusks as compared to the case for nonbiogenic aragonite which contains about five times as much strontium when precipitated under the same conditions.

2287. Buhler, D.R., R.M. Stokes and R.S. Caldwell. 1977. Tissue accumulation and enzymatic effects of hexavalent chromium in rainbow trout (Salmo gairdneri). Jour. Fish. Res. Bd. Canada 34:9-18.

Two-year-old rainbow trout reared for 2 yr in water containing about 0.00025 mg/l hexavalent chromium (Cr^{6+}) (Naches trout) or between 0.002 and 0.010 mg/l Cr^{6+} (Hanford trout) accumulated appreciable chromium, yielding whole body residues of about 0.029 and 0.180 mg/kg wet tissue, respectively. Naches trout after exposure for 22 days to 2.5 mg Cr^{6+}/1, showed highest concentrations, in mg Cr/kg wet wt in opercular bone (13.6), spleen (9.4), kidney (9.4), gall bladder (19.1) and bile (5.2); whole body Cr concentrations at 22 days was relatively low (0.87). Upon return of exposed fish to water containing 0.002-0.010 mg/l chromium, the metal was rapidly depleted from most tissues except kidney, liver, gill, gall bladder, and bile. Chromium accumulated in tissues of trout exposed to 2.5 mg/l Cr^{6+} was not distributed proportionately among the various subcellular fractions but concentrated in cell cytosol, especially liver and gill. Mitochondrial cytochrome oxidase, NADH-cytochrome c reductase, and succinate cytochrome c reductase activities in liver, kidney, gill, and brain tissues of Naches trout and Hanford trout exposed to 2.5 mg/l Cr^{6+} were not significantly different except for kidney NADH-cytochrome c reductase which was lower in Hanford and chromium treated fish. Microsomal nitroreductase, O-demethylase and NADPH-cytochrome c reductase and the soluble glucose-6-phosphate dehydrogenase activities in liver and kidney from Hanford trout were significantly lower than those of Naches trout. Exposure of Hanford trout to 2.5 mg/l Cr^{6+}, however, did not reduce the activities of these enzymes below control levels. In vitro studies showed that trout enzymes were fairly insensitive to Cr^{6+} inhibition. These results suggest that observed differences in enzyme activity between Naches and Hanford trout may be caused by factors other than chromium content of the water.

2288. Burrows, W.D. 1977. Aquatic aluminum: chemistry, toxicology, and environmental prevalence. CRC Critical Reviews in Environmental Control 7:167-216.

Acute effects of aluminum salts to freshwater and marine fishes, protozoans, crustaceans, molluscs, bacteria, algae, and higher plants, plus chronic effects to trout are reviewed. Environmental prevalence of aquatic aluminum in North America and selected sites in South America, Africa, and Asia and in seawater is listed. Also presented is data on chemistry of Al in water and its determination.

2289. Calabrese, A. 1975 (1976). Effects of heavy metals on embryonic and adult marine bivalves. Haliotis 5:121-125.

Results of selected studies on biological effects of 11 metals to bivalves were summarized. Mercury, Ag, Cu, and Zn were most toxic to embryos of oysters, Crassostrea virginica; Ni, Pb, and Cd were less toxic and Al, As, Cr, and Mn least toxic. Decreasing order of toxicity to clam, Mercenaria mercenaria, embryos was Hg, Ag, Zn, Ni, and Pb. LC-50 (96 hr) values for juvenile scallops, Argopecten irradians, showed Ag and Hg most toxic while Cd and As were less toxic. Oxygen consumption was increased by sublethal concentrations of Cd and Ag. Silver also induced oxygen consumption elevations in larval, juvenile, and adult clams, Spisula solidissima; gills accumulated up to 4X more Ag than body tissues. In general, oxygen consumption increased and was salinity-dependent in Crassostrea, Mercenaria, mussels Mytilus edulis, and soft shell clams Mya arenaria exposed to sublethal levels of silver for 96 hrs.

2290. Calabrese, A., R.S. Collier and J.E. Miller. 1974. Physiological response of the cunner, Tautogolabrus adspersus, to cadmium. I. introduction and experimental design. In: U.S. Dept. Commerce NOAA Tech. Report NMFS SSRF-681:1-3.

The cunner, a marine teleost, was exposed to five concentrations of cadmium as $CdCl_2$, at $25^{o}/oo$ salinity and $21-25^{o}C$. Cadmium levels tested, in mg/l, (and percent mortality in 96 hours) were: 0.0 (1.8); 3.0 (3.5); 6.0 (5.4); 12.0 (1.8); 24.0 (10.7); and 48.0 mg/l (26.8%).

2291. Calabrese, A., J.R. MacInnes, D.A. Nelson, and J.E. Miller. 1977. Survival and growth of bivalve larvae under heavy-metal stress. Marine Biology 41:179-184.

LC-5, -50, and -95 concentrations of mercury, silver, copper, nickel, and zinc salts to larvae of the oyster, *Crassostrea virginica*, and the clam, *Mercenaria mercenaria*, were determined. LC-50 (12 day) values for *C. virginica* were, in ug/l, 12 for Hg, 25 for Ag, 33 for Cu, and 12,000 for Ni. LC-5 and -95 values followed a similar pattern. LC-50 (8-10 day) values for *M. mercenaria*, in ug/l, were 15 for Hg, 16 for Cu, 32 for Ag, 195 for Zn, and 5,700 for Ni; LC-5 and -95 values showed the same order of sensitivity. Calculated growth of surviving larvae from both species, except clam larvae in nickel-treated water, was not reduced significantly at the LC-5 values of the five metals, but was reduced to 68 to 45% of original growth at the LC-50 values. No growth was observed for clam larvae at the LC-50 level of Ni. Embryos from both species were generally more sensitive than larvae to heavy metal toxicants, with Hg most toxic and Ni least toxic on the basis of LC-50 values.

2292. Calabrese, A., F.P. Thurberg, and E. Gould. 1977. Effects of cadmium, mercury, and silver on marine animals. U.S. Dept. Commerce, Marine Fish. Review 39(4):5-11.

Effects of various concentrations and exposure times of cadmium, mercury, and silver on marine molluscs, crustaceans, and fish are summarized. Data includes oxygen consumption, osmoregulation, enzyme activity, survival and other toxic effects, and is based on studies conducted at the Milford (Conn.) Lab of the Middle Atlantic Coastal Fisheries Center.

2293. Calamari, D. and R. Marchetti. 1975. Predicted and observed acute toxicity of copper and ammonia to rainbow trout (*Salmo gairdneri* Rich.). Prog. Water Technol. 7(3/4):569-577.

Trout were placed in cages at various depths for 48 hrs in Lake Orta, Italy, from March to September, when copper and ammonia concentrations varied from 0.006-0.066 mg Cu/l and from 5.8 to 7.2 mg N(NH_3 and NH_4+)/l. Mortality at different seasons was always higher in depths >15 m. A maximum of 67% kill occurred in August at 30 m, when water contained 0.056 mg Cu/l and 5.6 mg ammonia/l; 61% died in September at 25 m with 0.066 mg Cu/l and 5.1 mg ammonia/l, and 60% died in May at 25 m with 0.05 mg Cu/l and 4.7 mg ammonia/l. Survival increased from winter to summer in the upper layers; mortality dropped to only 0-10% in August and September when Cu ranged from 0.006 to 0.020 mg/l and ammonia from 5.1 to 7.2 mg N/l. Toxicity values for the field matched expected values from previous laboratory assays.

2294. Capuzzo, J.M. and J.J. Sasner. 1977. The effect of chromium on filtration rates and metabolic activity of *Mytilus edulis* L. and *Mya arenaria* L. *In*: Vernberg, F.J., A. Calabrese, F.P. Thurberg, and W.B. Vernberg (eds.) Physiological responses of marine biota to pollutants. Academic Press, N.Y.: 225-237.

Chromium, in dissolved and particulate forms, lowered filtration rates in *Mytilus*, and to a lesser extent, in *Mya* . Exposure of *Mytilus* to sediments from Pomeroy's Cove, New Hampshire (150 mg Cr/kg clay) and Fresh Creek (990 mg Cr/kg) for 24 weeks reduced filtration rates in direct proportion to Cr concentration. No significant difference was observed with Adam's Point sediment (10 mg Cr/kg). *Mytilus* and *Mya* reduced filtration rates when exposed to 1,200 mg Cr/kg kaolinite clay for 4-6 weeks. Uptake was probably due to diffusion of dissolved Cr, since Cr concentration of kaolinite decreased to 500 mg/kg over this period. In 1000 mg Cr/kg bentonite clay, which did not reduce in concentration, *Mytilus* but not *Mya* exhibited significantly lowered filtration rates. Exposure to 1.0 mg Cr/1 seawater resulted in reductions in filtering activity in both species of molluscs. Authors concluded that diffusion from seawater and particulate uptake were important pathways for Cr exposure in *Mytilus*, but only diffusion was important in *Mya*. *Mytilus* gills in 1.0 mg Cr/1 or 1000 mg Cr/kg bentonite showed slow, erratic movements of cilia; oxygen consumption of excised gill tissue was reduced.

2295. Chan, K.M. and J.P. Riley. 1966. The determination of vanadium in sea and natural waters, biological materials and silicate sediments and rocks. Analytica Chim. Acta 34:337-345.

Vanadium was concentrated from sea and natural waters by coprecipitation with iron hydroxide, separated from iron and other elements by ion exchange using hydrogen peroxide as a selective eluting agent, and determined photometrically with diaminobenzidine. The ion exchange process was also used to separate vanadium from other elements in the analysis of silicate rocks and three species of the marine algae: *Fucus vesiculosus*, *Laminaria digitata*, *Ascopyllum nodosum*. Concentration of vanadium (coefficient of variation) in seawater was 0.002 mg/1 (2.8%), in sediment 57.0 mg/kg (1.3%), in *Fucus* 2.2 mg/kg dry wt (2.5%), in *Laminaria* 1.8 mg/kg dry wt (2.5%), and in *Ascophyllum* 0.9 mg/kg dry wt (2.5%).

2296. Chau, Y.K. and P.T.S. Wong. 1976. Complexation of metals in natural waters. *In:* Andrew, R.W., P.V. Hodson, and D.E. Konasewich (eds.). Toxicity to biota of metal forms in natural water. Great Lakes Res. Advis. Bd., Stand. Comm. Sci. Basis Water Qual. Criteria, Intern. Jt. Comm. Res. Advis. Bd.:187-196.

Significant fractions of trace metals in natural waters are believed to exist in complexed forms together with miscellaneous organic ligands which regulate availability of these metals in the system as nutrients or as toxic agents. Metal concentrations in test water from several Ontario lakes showed high labile and total Zn, up to 0.27 mg/l and 0.33 mg/l, respectively, and maximum total Ni at 1.9 mg/l, total Cu at 0.02 mg/l, total Pb at 0.02 mg/l, and total Cd at 0.005 mg/l. No lake waters supported algal growth of *Ankistrodesmus falcatus* higher than 20% of a laboratory medium, possibly because of low complexing capacity of these metals. When 0.5 mg Pb/l, as $Pb(NO_3)_2$, was added to each lake, growth of the algae *Scenedesmus quadricauda* was inhibited to 10 to 70 % of controls. No lake could detoxicate this amount of Pb; however, a direct relationship between complexing capacity of water and algal growth was shown.

2297. Cheng, L., G.V. Alexander and P.J. Franco. 1976. Cadmium and other heavy metals in seaskaters (Gerridae: *Halobates*, *Rheumobates*). Water, Air Soil Poll. 6:33-38.

Concentrations of cadmium, copper, iron, lead, nickel and zinc were determined in the oceanic insects *Halobates sobrinus* and *H. sericeus*, and in *Rheumotobates aestuarius* collected from mangrove swamps. Mean metal levels, in mg/kg dry wt, for *H. sobrinus* were 152 Cd; 50 Cu; 289 Fe; 10 Pb; 18 Ni; 176 Zn. For *H. sericeus* these were 40 Cd; 45 Cu; 178 Fe; 7 Pb; 7 Ni; 176 Zn. Concentrations in *R. aestuarius* were >5 Cd; 64 Cu; 204 Fe; >2 Pb; 6 Ni; 197 Zn. Authors suggest that *Halobates* could become a useful environmental indicator owing to its large body size, distribution, and ability to accumulate trace metals, especially Cd.

2298. Cheng, T.C. 1975. Does copper cause anemia in *Biomphalaria glabrata*? Jour. Invert. Pathology 26:421-422.

Hemoglobin concentrations in freshwater gastropods, *B. glabrata*, showed no significant differences between snails exposed to 0.06 or 60.0 mg Cu/l as $CuSO_4$ for 12 hrs, or for 72 hrs, *vs* controls that had been starved for that period. Pigment cells in connective tissue matrix of the rectal ridge destroyed by Cu exposure were believed to be hemoglobin-synthesizing cells. It was concluded that either these cells do not serve this function, or sufficient cells exist in other parts of the body to mask loss due to cupric ions.

2299. Chervinski, J. 1977. Note on the adaptability of silver carp - *Hypophthalmichthys molitrix* (Val.) - and grass carp - *Ctenopharyngodon idella* (Val.) - to various saline concentrations. Aquaculture 11:179-182.

Survival of two carp species was observed in fresh water, and in 20% (7.8 o/oo), 25% (9.75 o/oo), and 30% (11.7 o/oo) seawater. Both species survived direct transfer from fresh water to 20% and to 25% seawater after 48 hrs. In 30%, all silver carp were dead, but 4/5 of the grass carp survived. After acclimatization to 20% seawater for 48 hrs, fish were transferred to 30%; most silver carp and grass carp survived. After acclimatization to 25% seawater and transfer to 30%, a mean of 0.5 of 5 silver carp and 2.4 of 5 grass carp were still alive. Upon transfer from fresh water to 25% seawater, no silver carp, and 3/4 of the grass carp survived after a month.

2300. Clubb, R.W., A.R. Gaufin and J.L. Lords. 1975. Acute cadmium toxicity studies upon nine species of aquatic insects. Environ. Research 9:332-341.

Continuous-flow bioassays were used to calculate LC-50 (96 hr) values for cadmium and freshwater insects. For stonefly, *Pteronarcella badia*, this was 18.0 mg Cd/l; and for mayfly, *Ephemerella grandis grandis*, it was 28.0 mg Cd/l. *Pteronarcella* was the most sensitive species tested. Mayflies, stoneflies, true flies, and caddisflies were relatively insensitive to cadmium (see table).

Percent survival at maximum cadmium concentration tested:

Species	mg Cd/liter	Days	Percent survival
Diptera (true flies)			
Atherix variegata	10.0	21	100

Hexatoma sp.	10.0	21	80
Holorusia sp.	42.5	7	50
Ephemeroptera (mayflies)			
Ephemerella grandis grandis	42.5	7	0
Plecoptera (stoneflies)			
Acroneuria pacifica	17.5	21	10
Arcynopteryx signata	17.5	21	10
Pteronarcella badia	42.5	7	0
Pteronarcys californica	14.0	14	100
Tricoptera (caddis flies)			
Brachycentrus americanus	42.5	7	100

P. badia held in 9.0 mg Cd/l solutions accumulated 19.0 mg/kg/day for the first 24 hr and minus 0.005 mg/kg/day during days 1-4. Post-treatment Cd loss of this group was minus 0.75 mg/kg/day, with loss rate appearing linear. Immature insects appear to be more sensitive to Cd than larger, mature insects. Long term studies suggest that cadmium inhibits molting frequency.

2301. Clubb, R.W., A.R. Gaufin and J.L. Lords. 1975.
Synergism between dissolved oxygen and cadmium toxicity in five species of aquatic insects. Environ. Research 9:285-289.

Continuous-flow bioassays were used to determine the relation between dissolved oxygen and cadmium upon *Acroneuria pacifica*, *Brachycentrus americanus*, *Ephemerella grandis grandis*, *Holorusia* sp. and *Pteronarcella badia* as measured by survival and body Cd burdens. Survival decreases with increasing oxygen concentration at given cadmium levels. Uptake of Cd and oxygen consumption increased at increasing dissolved oxygen concentrations. For all Cd levels tested, there was some survival after 2 weeks in all species during exposure to 1.0-5.0 mg Cd/l with dissolved oxygen ranging between 4.6 and 7.6 mg/l. Exposure of *P. badia* to 5.0 mg/l Cd at 3.8 mg/l D.O. for 96 hrs produced body residues of 7 to 114 mg Cd/kg; these values were significantly higher when D.O. was increased to 6.1 mg/l. Authors concluded that cadmium absorption may be coupled to metabolism.

2302. Conway, H.L, J.I. Parker, E.M. Yaguchi and D.L.
Mellinger. 1977. Biological utilization and

regeneration of silicon in Lake Michigan. Jour. Fish. Res. Bd. Canada 34:537-544.

Depth profiles of dissolved reactive silicon and amorphous particulate silicon were made at seven monthly intervals at stations along a southwest transect from Grand Haven, Michigan, to the approximate center of the southern basin of Lake Michigan. Biological utilization of reactive silicon occurred prior to stratification in early June. A shift from a 100% diatom-dominated phytoplankton community in spring to approximately 12% diatoms in August was attributed to the low dissolved Si level of <0.002 m mol/l in the surface water during summer. The total amount of biologically active silicon (TBAS) for the lake was approximately 0.019 m mol/l. Winter values were approximately 0.002 m mol/l amorphous silicon and 0.017 m mol/l reactive silicon. During the period June-August, 80% of TBAS had been utilized by the diatom community, with only 20% remaining as reactive silicon. Greater than 50% of TBAS was lost from the water column during spring and early summer; the loss was attributed to settling of diatom frustules and sinking of zooplankton fecal pellets containing frustules. This silicon was subsequently returned, in a soluble form, to deep water during the fall. The amount of TBAS recycled was estimated to be 80-100%.

2303. Conway, H.L. and P.J. Harrison. 1977. Marine diatoms grown in chemostats under silicate and ammonium limitation. IV. transient response of Chaetoceros debilis, Skeletonema constatum, and Thalassiosira gravida to a single addition of the limiting nutrient. Marine Biology 43:33-43.

The kinetic response of ammonium- or silicate-limited and ammonium- or silicate-starved populations of C. debilis, S. costatum, and T. gravida was determined by single addition of the limiting nutrient to a steady-state culture and subsequent monitoring of nutrient disappearance. Three distinct modes of uptake were observed for ammonium- or silicate-limited populations of these three species: surge uptake (V_s); internally (cellular) controlled uptake (V_i); and externally (ambient limiting nutrient concentration) controlled uptake (V_e). Non-limited populations did not exhibit the three distinct segments of uptake, V_s, V_i, and V_e. Estimates of the maximal uptake rate (V_{max}) and the Michaelis constant (K_s) were obtained from nutrient-limited populations during the V_e segment of the uptake curve. Pooled values of V_e for the three ammonium limited populations yielded V_{max} and K_s estimates of 0.16/hr and 0.5 ug-at NH_4/l. Kinetic data derived from the V_e segment of the uptake curve for silicate-limited populations yielded V_{max} values of 0.18/hr for *C. debilis*, 0.10 for *S. costatum*, and 0.03 for *T. gravida*. K_s was 2.2 ug at/l for *C. debilis*, 1.3 for *S. costatum*, and 0.3 for *T. gravida*. In a number of parameters that were measured, *T. gravida* was clearly different from *C. debilis* and *S. costatum* and its recovery from nutrieint starvation was the slowest. Recovery of all species from silicate limitation or starvation was slower than from ammonium lack.

2304. Crossland, C.J. and D.J. Barnes. 1977. Calcification in the staghorn coral, *Acropora acuminata*: variations in apparent skeletal incorporation of radioisotopes due to different methods of processing. Marine Biology 43:57-62.

Pieces of branch from *A. acuminata* were incubated for one hour with 7.7 mCi/mg Ca-45 Cl_2 and 0.6 mCi/mg NaHC-14 O_3 under identical conditions in light or in dark. After specimens were processed in different ways, tissues were digested in 20 ml N KOH. In both light and dark incubations, lowest radioactive incorporations into skeleton were obtained from specimens killed with liquid N_2 and left in running seawater. Ca-45 values were 230 dpm/mg protein in dark and 1320 in light regimes. The highest value of Ca-45 incorporation under dark conditions was 1000 dpm/mg protein when specimens were placed directly in KOH; this was 2730 under light conditions in methanol-chloroform-water. Skeletal activity of C-14 followed similar trends. Tissue activity of C-14 O_2 was low, 160 dpm/mg protein, when washed in seawater in dark; this was 310 in light. The highest value, when placed directly in KOH, was 2490 in dark and 2050 in light.

2305. Cunningham, P.A. 1976. Inhibition of shell growth in the presence of mercury and subsequent recovery of juvenile oysters. Proc. Nat. Shellfish. Assn. 66:1-5.

Juvenile oysters, *Crassostrea virginica*, were exposed for 12 hrs daily to 0.01 or 0.1 mg Hg/l as mercuric acetate for 47 days. Shell growth, used as an indicator of physiological stress, decreased significantly by day 15 in both concentrations. After 47 days, shell growth was reduced by 33% in 0.01 and by 77% in 0.1 mg/Hg/l. Oysters placed in seawater for a depuration period of 162 days demonstrated shell growth rates comparable to controls within 20 days for the 0.01 mg/l group and 34 days for the 0.1 mg/l group.

2306. Cutshall, N.H., J.R. Naidu and W.G. Pearcy. 1977. Zinc and cadmium in the Pacific hake Merluccius productus off the western U.S. coast. Marine Biology 44:195-202.

Mean levels of zinc and cadmium, respectively, in some northeast Pacific Ocean organisms in mg metal/kg wet wt were: euphausiids Euphausia pacifica 13.0, 0.23; pink shrimp Pandalus jordani muscle 11.0, 0.060; whole pink shrimp 58.0, 0.020; flatfish 4.0, 0.017; myctophids 10.0, 0.060; viperfish Chauliodus macouni 7.0, 0.098; sablefish Anoplopoma fimbria 4.0, 0.012; Pacific hake Merluccius productus muscle 4.0, 0.03; whole Pacific hake 12.0, 0.12; Puget Sound hake muscle 6.0, 0.012; and Puget Sound hake whole 15.0, 0.086. Zinc and cadmium levels in muscle tissue or whole Pacific hake increased with increasing total wet body weight, especially for smaller fish. These trends seem to be related to the euphausiid diet of hake which contains high amounts of both metals and also a high Cd:Zn ratio. No relationship between zinc and cadmium concentration and collection site was apparent for the isolated hake population in Puget Sound.

2307. Cutshall, N.H., J.R. Naidu, and W.G. Pearcy. 1977. Zinc-65 specific activities in the migratory Pacific hake Merluccius productus. Marine Biology 40:75-80.

Pacific hake, migrating northward along the California coastline during summer, accumulate radioactive zinc-65 associated with the southwesterly flowing plume of the Columbia River. Smaller fish reflect this contamination in both whole body and in muscle tissue earlier than larger fish. Fish weighing 0.5 kg wet wt have a Zn-65 concentration, in pCi/g wet wt whole fish, of about 0.3 at 41° 32'N latitude and 0.55 at 43° 23'N latitude, while fish weighing 1.25 kg have 0.2 and 0.45 respectively. Zn-65 specific activities increase toward the north as far as 46°N, off the mouth of the Columbia River, then decline northward along the coast of Washington state. In tissues and organs, Zn-65 concentrations in pCi/g ash, ranged from 145.5 in spleen and 110.5 in ovary to 1.6 in bone; total Zn in mg/kg ash, ranged from 4290 in liver and 3060 in ovary to 150 in bone; specific activity in nCi Zn-65/g, ranged from 92.5 in spleen to 10.7 in bone and 9.8 in skin.

2308. Danell, K., A. Anderson, and V. Marcstrom. 1977. Lead shot pellets dispersed by hunters--ingested by ducks. Ambio 6:235-237.

Incidence of ingested lead shot pellets in 928 ducks from nine species in Sweden during the hunting season was determined. Species containing pellets were Anas platyrhynchos, A. penelope, A. acuta, Aythya ferina, Aythya fuligula, and Bucephala clangula. Lead shot pellets were found in ducks from six of the eight localities sampled. Usually one or two pellets were present, but some ducks contained up to 62 pellets. As the incidence of ingested pellets in this study is approximately equal to that found in North America, where the annual duck loss due to lead poisoning is estimated to be 2 to 3% of the population, it may be assumed that lead poisoning is a factor in mortality of Swedish ducks as well.

2309. Dawson, M.A., E. Gould, F.P. Thurberg and A. Calabrese. 1977. Physiological response of juvenile striped bass, Morone saxatilis, to low levels of cadmium and mercury. Chesapeake Science 18:353-359.

Juvenile bass were exposed to 0.5, 2.5, and 5.0 ug/l of cadmium as cadmium chloride for 30 to 90 days or to 1.0, 5.0, and 10.0 ug/l of mercury as mercuric chloride for 30 to 120 days. Following the longest exposure to each metal, the fish were allowed to recover for 30 days in running seawater. Gill-tissue respiration, glucose-6-phosphatase, malic enzyme, aspartate aminotransferase, and magnesium activation of AAT were measured. Fish exposed for 30 days to 0.5, 2.5 and 5.0 ug Cd/l consumed significantly less O_2 than controls. Exposure to 5 ug Hg/l for 30 days decreased respiration to 1.096 ul O_2/hr/mg compared to 1.742 for controls. At 10 ug Hg/l respiration rates were 0.97 after 30 days, 0.75 after 60 days and 0.94 after 120 days. There was no significant difference in enzyme activity during exposure to either metal; however, fish held in Cd-free seawater for 30 days following exposure to cadmium exhibited a slight drop in liver AAT and G6PdH.

2310. deFreitas, A.S.W., M.A.J. Gidney, A.E. McKinnon, and R.J. Norstrom. 1977. Factors affecting whole-body retention of methyl mercury in fish. In: Drucker, H. and R.E. Wildung (eds.). Biological implications of metals in the environment. ERDA Symp. Ser. 42:441-451. Avail. as CONF-750929 from Nat. Tech. Inf. Serv., U.S. Dept. Comm. Springfield, VA. 22161.

Efficiency of methylmercury assimilation from the gastrointestinal tract of fish ranged from 71 to 92% of amount of food ingested. Northern pike Esox lucius, perch Perca flavescens, brown bullhead Ictalurus nebulosus, and ling Lota lota, were fed minnows injected with Hg-203 methylmercury, while red horse suckers Moxastoma spp., white suckers Catastomus commersoni, and goldfish Carassius auratus, were given food containing tracer methylmercury. Variation in assimilation efficiency was not associated with food type, fish body size, or species. A positive correlation was observed between dose rate and retention index of methylmercury, but whole-body retention, using goldfish, was not affected by temperature or growth rate. The equation relating clearance rate and fish body weight did not appear to be species specific, and seemed to fit measured levels of methylmercury in yellow perch.

2311. Dethlefsen, V. 1977. Uptake, retention, and loss of cadmium by Crangon crangon. Inter. Coun. Explor. Sea. Fish. Improv. Comm. C.M. 1977/E:12. 21 pp. (mimeo).

After first molt, shrimp were exposed to Cd concentrations of 0.005-0.100 mg/l as $CdCl_2$ for up to 40 days. Uptake curves showed rapid accumulation during the first 3 days, followed by long-term linear accumulation of total body load. In 0.005 mg Cd/l, Crangon accumulated 1.3 mg Cd/kg dry wt after 3 days and 3.0 after 30 days. In 0.020 mg Cd/l, levels in shrimp were 2.0 mg Cd/kg dry wt at 1 day and 7.0 at 30 days. Cd concentration in exuvia of Crangon exposed until their second molt was not significantly lower than whole organism. Retention of Cd for 7-12 days was almost complete. After exposure for 20 days to 0.005 and 0.010 mg Cd/l, little change was seen 30 days later in body concentration. After 20 days exposure to 0.020 mg Cd/l, Cd levels dropped from 5.5 to 4.5 mg/kg dry wt by 27 days. Crangon from the Elbe estuary in 1975-1977 contained 0.4 to 1.1 mg Cd/kg dry wt; natural levels of Cd in water averaged 0.0001 mg/l.

2312. Dethlefsen, V., H. V. Westernhagen, and H. Rosenthal. 1975. Cadmium uptake by marine fish larvae. Helgol. wiss. Meeresunters. 27: 396-407.

Eggs of herring Clupea harengus, flounder Platichthys flesus, and garpike Belone belone, were incubated in 0.05-5.00 mg Cd/l at 15.7-32 o/oo salinity and 10 C. Newly hatched larvae were analyzed for Cd content. Cadmium residues in larvae were dependent on Cd concentrations employed during incubation. Cd levels in newly hatched flounder and herring larvae, at 7.0 to 23.0 mg Cd/kg dry wt, were 100X higher than in garpike larvae under the same conditions, at 0.017-0.019 mg/kg. Cadmium content of herring larvae increased to a maximum of 480 mg/kg dry wt after 8 days in 0.4 mg Cd/l; in flounder larvae it was 58 mg Cd/kg dry wt after 8 days in 0.5 mg Cd/l. After 34 days in 0.05 mg Cd/l, garpike larvae contained 0.097 mg Cd/kg dry wt, significantly higher than controls. No detrimental effects were shown for garpike larvae grown in up to 2.0 mg Cd/l for about 30 days.

2313. Dorn, P. 1974. The effects of mercuric chloride upon respiration in Congeria leucophaeata. Bull. Environ. Contamin. Toxicol. 12:86-91.

Respiration rates of the marine bivalve mollusc C. leucophaeata were measured after exposure for 48 h to 0.001, 0.01, 0.1, 1.0 or 10 mg mercury/l as $HgCl_2$. Mean respiration rates in ml O_2/g/hr, were respectively: 1.6 (controls); 1.9; 2.4; 2.7; and 2.9 (1.0 mg Hg/l). There were no survivors at 10 mg Hg/l; 80% survived 1.0 mg/l; no deaths were recorded at lower concentrations after 48 h. Departure of respiratory rates from controls was significant at Hg concentrations above 0.01 mg/l. Mercury binds to membranes altering ionic distribution and osmoregulatory activity and this may account for increased respiratory rates in Congeria.

2314. Draggon, S. 1977. Interactive effect of chromium compounds and a fungal parasite on carp eggs. Bull. Environ. Contamin. Toxicol. 17:653-659.

Effects of hexavalent and trivalent chromium compounds on a fungal parasite, Saprolegniales, and carp egg hatchability were reported at levels of 0.1, 0.3, 1.0, 3.0, 10.0, 15.0, 20.0 and 30.0 mg Cr/l for 6 day periods. Sodium chromate inhibited egg hatching at 0.1 and 0.3 mg Cr/l and stimulated hatching at all higher levels. Both chromium acetate and chromium chloride inhibited hatching at 0.1 to 3.0 mg/l, while higher concentrations were lethal. Sodium chromate stimulated fungal growth at 0.1 and 0.3 mg/l, but higher Cr levels inhibited growth. Fungal growth was stimulated by the three lowest levels of chromium acetate, significantly at 0.1 mg/l; growth decreased at 20.0 and 30.0 mg/l and was significantly lower at 3.0, 10.0 and 15.0 mg/l. Chromium chloride stimulated fungal biomass at 0.1 to 3.0 mg/l;

concentrations of 10.0 to 30.0 mg/l inhibited growth. Comparison of data revealed that increased egg mortality and increased fungal growth were coupled at low Cr concentrations. A mechanism for interaction of chemical and biological stress on carp egg survival in natural systems is presented.

2315. Drescher, H.E., U. Harms, and E. Huschenbeth. 1977. Organochlorines and heavy metals in the harbour seal _Phoca vitulina_ from the German North Sea Coast. Marine Biology 41:99-106.

Tissues of healthy, sick, and dead _P. vitulina_ from North German Waddensea were analyzed for heavy metals and organochlorines. Cadmium concentrations ranged from 0.01 to 0.20 mg/kg wet wt in liver, 0.002 to 0.024 in brain, and 0.06 to 0.38 in kidney. Copper ranged from 2.6 to 17.0 mg/kg wet wt in liver and about 2.3 to 4.0 in both brain and kidney. Lead concentrations were 0.10 to 0.57 mg/kg wet wt for both kidney and liver, and 0.20 to 0.04 in brain. Amounts of total mercury were 1.5 to 160.0 mg/kg wet wt in liver, 1.6 to 12.5 in kidney, and 0.11 to 1.4 in brain. Zinc concentrations ranged from 27.0 to 56.0 mg/kg wet wt in liver, 16.3 to 32.5 in kidney, and 10.8 to 15.0 in brain. Cadmium, Hg, and Pb levels increased with age of the individuals. DDT concentrations ranged from 2.2 to 27.2 mg/kg wet wt in blubber; kidney, liver, and brain all had <0.6 mg/kg. PCB content ranged from 27.3 to 564.0 mg/kg wet wt in blubber, 0.2 to 2.9 in brain, 0.06 to 2.70 in liver, and 0.18 to 1.22 in kidney. Lindane and Dieldrin both ranged from 0.04 to 0.98 mg/kg wet wt in blubber. Brain, liver, and kidney all had < 0.002 mg/kg. No relationship with age and pesticide levels was found, since even young seals were contaminated. There was no clear evidence that concentrations of any compound had negative effects on health of the seals; however, possible combined effects cannot be exluded.

2316. Eisler, R. 1977. Acute toxicities of selected heavy metals to the softshell clam, _Mya arenaria_. Bull. Environ. Contamin. Toxicol. 17:137-145.

Static acute toxicity bioassays with adult softshell clams and salts of copper, cadmium, zinc, lead, manganese, and nickel were conducted at 30 o/oo salinity and 22 C. Concentrations fatal to 50% in 168 hrs, in mg/l (ppm) metal added at start, were 0.035 for Cu, 0.150 for Cd, 1.55 for Zn, 8.80 for Pb, 300.0 for Mn, and > 50.0 for Ni. Additional tests were conducted with Zn^{2+} and Cu^{2+} at 30 o/oo during fall (17.5 C) and winter (4 C); clams displayed increasing survival with decreasing temperature. For Cu, LC-50 (336 hr) values at 17 C and 4 C were 0.086 and >3.00 mg/l, respectively; for Zn these were 2.65 and >25.0, respectively.

2317. Eisler, R. 1977. Toxicity evaluation of a complex metal mixture to the softshell clam _Mya arenaria_. Marine Biology 43:265-276.

Adults of the softshell clam were continuously subjected to a flowing raw seawater solution containing a mixture of salts of manganese, zinc, lead, nickel, copper, and cadmium. Final calculated concentrations, in ug/l, of the toxicant solution were 7200 Mn, 2500 Zn, 70 Pb, 50 Ni, 50 Cu and 1 Cd. These concentrations approximated highest measured levels within surficial interstitial sediment waters from mid-Narragansett Bay, Rhode Island. _M. arenaria_ were also subjected to a 20% solution, _i.e._, _1440 Mn, 500 Zn_, 14 Pb, 10 Ni, 10 Cu, and 0.2 ug/l Cd. _One_ study was conducted for 112 days in winter at 0 to 10 C, and another for 16 days in summer at 16 to 22 C. In the winter study, all clams exposed to a 100% solution died between the 4th and 10th week; soft parts of survivors at 6 wks contained about 19 times more Pb (13.3 mg/kg wet wt), 15X more Zn (140.5 mg/kg), 12X more Cu (24.6 mg/kg), 10X more Mn (66.0 mg/kg), 3X more Ni (1.2 mg/kg wet wt), and 0.1X more Cd (3.6 mg/kg wet wt) than controls. Relatively minor changes in whole body elemental content of Ca, Cr, Fe, K, Mg, Na, Sr, and V were observed. Clams exposed to a 20% solution during winter survived the 112 day study and contained about 5X more Cu, 4X more Mn, 3X more Zn and about 2X more Pb than controls; comparatively minor changes were observed in other elements examined. In the summer study, all _M. arenaria_ subjected to the 100% solution died between _6 and 14 days_. Survivors from this group at 7 days contained about 25X more Pb, 13X more Cu, 11X more Zn, 7X more Mn, and 3X more Ni than controls; other changes in elemental content were not as pronounced. Mortality in the 20% group during summer was slightly higher than controls during the 16 day study; at 14 days survivors from this group contained about 12X more Mn, 7X more Pb, 7X more Zn, 4X more Cu, and 3X more Ni than controls. Survival and bioaccumulation patterns in _Mya_ were not altered through feeding a supplemental diet of algae. Results of 14 day static acute toxicity bioassays with the metal mixture at 4 C demonstrated that softshell clam, quahaug clam _Mercenaria mercenaria_ and mahogany clam _Arctica islandica_ _were up to_ 3X more resistant than killifish *Fundulus heteroclitus* and up to 10X more resistant than rock crab *Cancer irroratus*. The significance of these findings are discussed in terms of potential environmental perturbations, especially local dredging practices.

2318. Eisler, R. and R.J. Hennekey. 1977. Acute toxicities of Cd^{2+}, Cr^{+6}, Hg^{2+}, Ni^{2+}, and Zn^{2+} to estuarine macrofauna. Arch. Environ. Contamin. Toxicol. 6:315-323.

Static acute toxicity bioassays were conducted at 20 C and 20 o/oo salinity with $CdCl_2 \cdot 2\frac{1}{2}H_2O$, K_2CrO_4, $HgCl_2$, $NiCl_2.6H_2O$ and $ZnCl_2$ using adults of starfish *Asterias forbesi*, sandworm *Nereis virens*, hermit crab *Pagurus longicarpus*, softshell clam *Mya arenaria*, mudsnail *Nassarius obsoletus*, and mummichog *Fundulus heteroclitus*, a fish. Concentrations (mg/l metal) fatal to 50% of the organisms in 168 hr ranged from 0.004 (clam) to 0.8 (mummichog) for mercury; 0.7 (clam, worm, crab and starfish) to 40.0 (mummichog) for cadmium; 0.2 (crab) to 52.0 (mummichog) for zinc; 0.7 (sandworm) to 44.0 (mummichog) for hexavalent chromium; and 13.0 (starfish) to 150.0 (mummichog) for nickel. Biocidal action was restricted to a relatively narrow range for all species-metals combinations tested: *i.e.* mean LC-75/LC-25 ratios for individual metals at 168 hr ranged between 2.82 (Zn) and 6.02 (Cd); for individual species this ratio extended from 2.76 (fish) to 4.46 (clam). It appears that acute toxicity evaluation of potentially hazardous metals in saline environments requires utilization of at least several representative species from divergent taxonomic categories and ecological niches.

2319. Eisler, R., D.J. O'Neill, Jr. and G.W. Thompson. 1978. Third annotated bibliography on biological effects of metals in aquatic environments. (No. 1293-2246). U.S. Environ. Prot. Agen. Rept. 600/3-78-005: 487 pp. Avail. from U.S. Dept. Comm., Nat. Tech. Inform. Serv., Springfield, VA. 21161.

Titles of 954 technical articles are listed on the subject of toxicological, physiological, and metabolic effects of stable and radio-labelled chemical species of metal cations to marine, estuarine and freshwater flora and fauna. Each reference was annotated and subsequently indexed by metal, by taxa, and by author in cumulative indices which encompass the present volume and the initial volumes in this series (Eisler, R. 1973. Annotated bibliography on biological effects of metals in aquatic environments (No. 1-567). U.S. Environ. Prot. Agen. Rep. R3-73-007: 287 pp; Eisler, R. and M. Wapner. 1975. Second annotated bibliography on biological effects of metals in aquatic environments (No. 568-1292). U.S. Environ. Prot. Agen. Rept. 600/3-75-008: 400 pp.).

2320. Elder, J.F. 1977. Iron uptake by freshwater algae and its diel variation. *In*: Drucker, H. and R.E. Wildung (eds.). Biological implications of metals in the environment. ERDA Symp. Ser. 42:346-357. Avail. as CONF-750929 from Nat. Tech. Inf. Serv., U.S. Dept. Comm., Springfield, VA. 22161.

A mixed algal community of primarily *Aphanizomenon*, *Staurastrum*, and *Fragilaria* increased its chlorophyll content from 65% to 150% of control values over 6 days in 0.01 mg iron/l. Primary productivity, as measured by C-14 uptake, was 200% of controls after 1 day in 0.01 mg Fe/l, 180% in 0.01 mg Fe/l and 1.0 uM EDTA, and 120% in 1.0 uM EDTA alone. Total dissolved iron in Lake Perris, California, reached a maximum of almost 0.03 mg/l at a depth of 4-8 m at 1:00 AM, in both February and June. Maximum Fe uptake by algae was also at 1:00 AM in June at the lake surface and at 8 m depth. At 8:00 PM, uptake was only 5-10%. Author postulates that at daybreak, dissolved iron is rapidly accumulated by algal cells, resulting in a decrease of Fe in the lake. Fe uptake drops sharply in the morning and then more gradually throughout the day. At sunset, Fe is released by algal cells, increasing Fe levels in the water; potential for iron uptake increases so that the uptake cycle repeats itself at daybreak.

2321. Elder, J.F. and A.J. Horne. 1977. Biostimulatory capacity of dissolved iron for cyanophycean blooms in a nitrogen-rich reservoir. Chemosphere 6:525-530.

Total dissolved iron, in mg/l, in Lake Perris, California was determined. Between February and September, 1975, Fe ranged between 0.015 and 0.025 mg/l in March and early April at depths up to 16 m and was < 0.011 at other times analyzed, except for a high of 0.053 in September at 16 m. In October, Fe increased from 0.005-0.015 to 0.09-0.100 mg/l between 8 and 16 m. When 0.01 mg Fe/l was added to water, along with N at lake values of 0.07-0.14 and P at 0.01-0.03 mg/l, the primary productivity of lake phytoplankton increased to 225%

that of controls on days 1 and 4, as measured by C-14 uptake. N and P addition alone only increased productivity 125%. Chlorophyll amounts increased to 220% on day 6, after initial decline to 70%, with Fe, N, and P additions. N and P alone showed chlorophyll increases to 150%. Abundance of the blue-green algae _Aphanizomenon flos-aquae_ increased to 0.4 mm^3/l from 0.08, 5 days after adding Fe, N, and P; N and P showed no increase. Number of heterocysts also increased in Fe, N, and P. Algal counts showed that influence of iron was primarily on blue-green algae, and this accounted for chlorophyll and productivity increase in the entire phytoplankton community.

2322. Enk, M.D. and B.J. Mathis. 1977. Distribution of cadmium and lead in a stream ecosystem. Hydrobiologia 52:153-158.

Cadmium and lead concentrations were measured in aquatic insects, teleosts, snails, water and sediments from an impacted freshwater stream. Concentrations of both metals increased from water fish sediments invertebrates. Measured Cd and Pb concentrations in selected species follow.

	Lead, in mg/kg wet wt	Cadmium, in mg/kg wet wt
Aquatic Insects		
Mayflies		
Isonychia sp.	6.83	1.19
Damselflies		
Agrion sp.	12.59	1.54
Caddis flies		
Cheumatopsyche sp.	11.00	0.81
Hydropsyche sp.	6.85	0.53
Fishes		
Carpiodes carpio	2.55	0.08
Etheostoma flabellare	2.88	0.15
Micropterus dolomieui	2.47	0.10
Snails		
Physa sp.	13.64	—
Sediments	8.30	0.14
Water (mg/l)	0.5	< 0.02

2323. Fargo, L.L. and R.W. Fleming. 1977. Effects of chromate and cadmium on most probable number estimates of nitrifying bacteria in activated sludge. Bull.

Environ. Contamin. Toxicol. 18:350-354.

Most probable number (MPN) estimates of two species of bacteria from activated sludge samples at sewage treatment facilities were made in media containing several concentrations of K_2CrO_4 or $CdCl_2$. Nitrosomonas populations from both San Jose Creek and Whittier Narrows were reduced in 1.0 mg K_2CrO_4/kg to 0.01 x 10^5/ml and in 10.0 mg/kg to 1.0-3.0/ml, from control values of 1.4-7.9 x 10^5/ml. Concentrations of 0.01 and 0.1 K_2CrO_4 had little effect on growth. $CdCl_2$ did not cause significant inhibition of Nitrosomonas at 0.1, 1.0, 10.0, and 100.0 mg/kg. MPN reduced from 1.4-7.9 x 10^5 to 0.49-1.10 x 10^5/ml as Cd levels increased. Nitrobacter from both sites was not inhibited significantly in up to 10 mg K_2CrO_4/kg, as MPN ranged from 1.3 x 10^5 to 2.3 x 10^4 over experimental concentrations. In $CdCl_2$, bacteria numbers decreased slightly, from control values of 3.3-7.0 x 10^4 to 0.46-1.3 x 10^4 in 100.0 mg Cd/kg.

2324. Farmer, G.J., J.A. Ritter, and D. Ashfield. 1978. Seawater adaptation and parr-smolt transformation of juvenile Atlantic salmon, Salmo salar. Jour. Fish. Res. Bd. Canada 35:93-100.

Presmolts and smolts, 1 and 2 year old salmon, adapted to seawater equally well as salinity was increased from 0.1 to 31.0 o/oo; marine osmoregulatory mechanisms apparently function before the completion of parr-smolt transformation. Adaptation was possible for parrs exceeding 12-13 cm fork length. As salinity increased to 31 o/oo, osmolarity of urine increased from about 50 to 300 mOsm/l, and serum and intestinal fluid rose from about 300 to 350 mOsm/l in juvenile salmon ≥ 14 cm; in 31 o/ooS, serum and intestinal fluid of parr were about 450 mOsm/l. Timing of transformation for 1 and 2 yr old juveniles was synchronous, as shown with lipid and moisture content and condition factor (K). A decrease of K factor and lipids in salmon from New Brunswick resulted in maximum migratory activity in mid-May, and at a slightly earlier date in Nova Scotia. Smolt-release dates are discussed with development of marine osmoregulatory mechanisms and timing of parr-smolt transformations.

2325. Flegal, A.R. 1977. Mercury in the seston of the San Francisco Bay Estuary. Bull. Environ. Contamin. Toxicol. 17:733-738.

Seston of three sizes (20 um, 76 um, and 366 um) from

San Francisco Bay estuary were analyzed for total mercury. Levels of mercury in the 20 um seston sample ranged from 0.22 to 3.7 mg/kg dry weight; the range in 76 um seston was 0.08-13.3; and was 0.09-1.1 in the 366 um seston. Mercury levels in seston varied temporarily, spatially with size, and with organic content, and appear to be higher in phytoplankton and/or organic detritus than in zooplankton.

2326. Flegal, A.R. and J.H. Martin. 1977. Contamination of biological samples by ingested sediment. Marine Poll. Bull. 8:90-92.

An inorganic residue, presumed to be ingested sediment, was found in the gastropods *Tegula funebralis* and *Acmaea scabra* and copepods *Acartia tonsa* and *A. clausi*. Expressed as a percentage of sample weight, residue fraction correlated positively and significantly with iron, manganese, and titanium in *T. funebralis* and iron and manganese in *A. scabra* from the California and Mexico coast. Correlations between residue fraction and Ag, Cd, Cu, Ni, Sr, and Zn in these two species varied from highly significant negative correlations at some collection sites to highly positive correlations at others. Because inorganic matter correlated significantly with elemental composition of marine invertebrates in several cases, authors suggest that this should be considered during chemical analysis of marine organisms.

2327. Foster, P.L. 1977. Copper exclusion as a mechanism of heavy metal tolerance in a green alga. Nature 269:322-323.

Chlorella vulgaris from the River Hayle, England, where copper is found at 0.12 mg/l, showed decreased growth as copper concentration increased to 1.0 mg/l as $CuSO_4$. At 1.0 mg/l growth was low but not zero. Growth of a non-tolerant strain of *Chlorella* from unpolluted waters, *i.e.* $\leq$0.002 mg Cu/l, was arrested in as little as 0.05 mg Cu/l, and was completely inhibited in 0.30 mg/l. At 0.25 mg Cu/l, non-tolerant *Chlorella* accumulated about 0.11% dry wt as copper while tolerant *Chlorella* contained about 0.01%; at 1.0 mg Cu/l, tolerant strains accumulated only 0.08% dry wt. The relation between decreasing growth rate and increasing amount of copper as % dry wt was identical for both strains of *Chlorella*, implying that they respond similarly to the same amount of cellular Cu. It was concluded that Cu exclusion was the only mechanism of tolerance in this alga.

2328. Fowler, S.W. 1977. Trace elements in zooplankton particulate products. Nature 269:51-53.

Whole bodies of euphausiids, *Meganyctiphanes norvegica*, from surface waters off Monaco contained high levels of Sr at 117 mg/kg dry wt, Fe at 64, Zn at 62 and Cu at 48 mg/kg. Amounts of Se, Mn, Pb, Cr, Cd, Ag, Ni, Hg, Ce, Co, Sb, Cs, Sc, and Eu, in descending order, were all <4.5 mg/kg dry wt. Maximum concentrations in moults were generally higher, at 350 mg/kg dry wt for Sr, 232 for Fe, and 146 for Zn; Pb was 22 mg/kg, Ni was 6.7, and Sb 0.8. Fraction of body burden contained in moults for these elements was as follows: Pb about 150%, Sb 87%, Ni 78%, Fe 28%, Sr 23%, and Zn 18%. Iron and zinc were high in euphausiid eggs with 330 mg Fe/kg dry wt and 318 mg Zn/kg. In faecal pellets, maximum amounts of metals were 24,000 mg Fe/kg dry wt, 950 for Zn, 243 for Mn, 226 for Cu, and 200 for Ce; all others were <80 mg/kg dry wt. Faecal pellets contained significantly higher levels of each element than whole euphausiids, except for Sr, Hg, and Sc. Metal levels in microplankton, consisting of copepods, chaetognaths, phytoplankton, and detritus, were 570 mg Fe/kg dry wt, 520 for Sr, 483 for Zn, and <20 mg/kg dry wt for remaining metals. Concentration ratios in pellets from the microplankton diet were high for non-biologically essential elements such as Ce, Cs, Sc, Sb, and Eu; high concentration of Fe may be due to ingestion of a form not easily assimilated. Flux rate by euphausiids due to faecal pellets was 910 mg/kg euphausiid per day for Fe, 36 for Zn, and 9.2-1.4 for Ce, Cr, Cu, Mn, Pb, Sb, and Sr; other metals were <0.8 mg/kg per day. Flux rate due to moults was much lower for all metals except Sr at 3.2 mg/kg/euphausiid/day.

2329. Frederick, R.B. 1976. Effects of lead nitrate ingestion on open-field behavior of mallard ducklings. Bull. Environ. Contamin. Toxicol. 16:739-742.

Nine day-old mallard ducklings were fed a diet consisting of 5.0, 50.0 or 500.0 mg/kg lead as lead nitrate and duckling movements were measured 3 or 8 days later. Differences in open-field performances were insignificant. Mean percentage weight gains of ducklings after eight days of treatment were: 182 for controls; 158 at 5.0 mg Pb/kg; 190 at 50 mg/kg and 191 at 500 mg/kg.

2330. Friedrich, A.R. and F.P. Filice. 1976. Uptake and accumulation of the nickel ion by *Mytilus edulis*.

Bull Environ. Contamin. Toxicol. 16:750-755.

Uptake and accumulation of nickel by mussels during exposure for 4 weeks was measured in synthetic seawater containing 0.013, 0.025, 0.051, or 0.102 mg Ni/l. At 0.018 and 0.03 mg Ni/l, uptake and accumulation was not significantly different from controls. In groups exposed to 0.056 and 0.107 mg Ni/l, nickel levels in tissue were approximately 33 and 41 mg Ni/kg dry wt, respectively. Some mussels died during the four week experiment but no correlation with increasing Ni concentration was established. An additional 96 hr study was conducted in Ni concentrations of 20, 40, and 80 mg/l; mussels were not fed during this experiment. No animals died during the 96 hr experiment. Analysis of soft tissue after a 96 hr exposure to 20, 40 and 80 mg Ni/l showed nickel levels of approximately 420, 450 and 820 mg Ni/kg dry wt, respectively. Nickel uptake may occur through mucus sheet or via transmembrane absorption.

2331. Fuller, R.H. and R.C. Averett. 1975. Evaluation of copper accumulation in part of the California Aqueduct. Water Res. Bull., Amer. Water Res. Assoc. 11:946-952.

Copper sulfate has been used extensively in the California Aqueduct to control phytoplankton and the alga Cladophora; since 1969 more than 110,000 kg have been added. Analysis of water showed no significant increase of copper in the treated area over untreated water. Twenty-four samples contained <10 mg Cu/l, 3 other sites had Cu concentrations of 20, 30, and 50 mg/l. Sediments from treated areas contained 59.7 mg Cu/kg dry wt compared to 29.8 mg/kg in controls, or about a 100% increase. Mean copper concentrations in 5 species of freshwater algae from treated sites increased 200%, ranging from 19 to 47 mg/kg dry wt; in untreated areas, levels were 8-15 mg/kg. The clam Corbicula showed a 68% increase of Cu in tissues from controls of 56.4 mg/kg dry wt to 94.8 mg/kg from areas where $CuSO_4$ was added. Shells of clams contained 13.1 mg Cu/kg dry wt, a 39% increase over 9.4 mg Cu/kg found in untreated areas. Copper levels in the snail Helisoma from treated sites were 41.5 mg/kg dry wt, a 77% increase over control values of 23.5 mg/kg. Authors state that none of the concentrations found were considered harmful to biota.

2332. Galtsoff, P.S. and V.L. Loosanoff. 1939. Natural history and method of controlling the starfish (Asterias forbesi, Desor). Bull. U.S. Bur. Fish. XLIX (31):75-132.

Copper sulfate and other chemicals were tested for starfish population control. Groups of five starfish in $24^{o}/oo$ S took 0.1 to 3 min to die in 1,000 mg $CuSO_4$/l, 0.25 to 5 min in 500 mg/l, 1.0 to 35 min in 100 mg/l, 1.3 to 75 min in 50 mg/l, 3 to 110 min in 20 mg/l and 5 to 150 min. in 10 mg/l. No effect was shown in 1.0 or 5.0 mg Cu SO_4/l for 24 hrs. Tolerance to Cu increased as starfish size increased. Three starfish were used with one oyster per tank in a second test for practical purposes of starfish control in nature. After 7 days in 0.07 mg $CuSO_4$/l, all were alive. Two starfish and the oyster died by day 7 in 0.15 mg/l, all starfish died by day 5 and the oyster on day 6 in 0.31 mg/l; all starfish by day 2 and the oyster on day 3 in 0.62 mg/l, and all starfish by day 1 and the oyster on day 2 in 1.25 mg $CuSO_4$/l. With 150 mg zinc sulfate in 2 cu ft tanks, starfish turned aborally were unable to right themselves after 1 day; one of the five died on day 5. Various chromium salts, ranging in concentration from 0.08 to 10.0 mg/l, had little effect on starfish. Calcium oxide, at 300 lbs/acre of bottom in experimental tanks killed all starfish within 5 to 10 days. On 25 acres of starfish-infested oyster beds, treated with 480 lbs calcium oxide/acre, up to 80% of starfish were effected by skin lesions 1 week after application.

2333. Gentner, S.-R. 1977. Uptake and transport of iron and phosphate by Vallisneria spiralis L. Aquatic Botany 3:267-272.

Using Fe-59 and P-32 as tracers, uptake and transport of iron and phosphate from the medium by roots and tissues of the vascular freshwater aquatic plant V. spiralis were studied. Fe-59 levels in shoots varied from 0.9 to 48.5 x 10^3 cpm/gm wet wt when water Fe ranged from 0.03 to 0.63 x 10^3 cpm/ml. Maximum concentration factor of plant to water was 96 for roots. Roots accumulated more iron than shoots. Fe levels in roots varied from 3.3 to 49.1 x 10^3 cpm/gm wet wt, with concentration factors up to 152. Phosphate was taken up equally by roots and shoots. Transport within the plants occurred principally in the tissue to root direction.

2334. George, S.G. and R.L. Coombs. 1977. The effects of chelating agents on the uptake and accumulation of cadmium by Mytilus edulis. Marine Biology 39:261-268.

Uptake, storage, and excretion of cadmium by mussels was studied at sub-lethal concentrations using Cd-115m as a marker. Maximum accumulation of Cd in soft tissues was 0.018 mg/kg dry wt at 1500 ug/l $CdCl_2$ in seawater after 5 days. The concentration factor (mg/kg in tissue divided by mg/l in medium) was highest, 1.7×10^{-2}, at 700 ug/l Cd in water. Accumulation of Cd by mussels exposed to 200 ug $CdCl_2$/l over 20 days showed a high concentration factor of 3.75×10^{-3} in kidney, while visceral mass, gills, mantle, and muscle were much lower; ratios were approximately 44:11:10:4:2. Exposure for 21 days to 100 ug Cd/l as complexes with EDTA, alginic acid, humic acid, or pectin showed all with a rate of accumulation into each tissue twice that of $CdCl_2$ in seawater. During cadmium accumulation in 200 ug $CdCl_2$/l for 20 days, there was a marked decrease of iron in mantle, a slight decrease of copper in viscera, and slight increases of iron, copper, and zinc in muscle, and of copper in gills. After exposure to 100 ug $CdCl_2$/l for 2 days, mussels lost linearly up to one third of the absorbed cadmium over the next 11 days; excretion rate was 18 times slower than uptake rate.

2335. Gergely, A., K. Soós, L. Erdélyi and V. Cieleszky. 1977. Determination of mercury in fish from rivers and lakes in Hungary by atomic absorbtion technique. Toxicology 7:349-355.

Mercury levels in muscle from 9 species of fish collected from all important rivers and lakes in Hungary averaged 0.36 mg Hg/kg wet wt. Average levels of different samples ranged from 0.10 mg Hg/kg for bass _Aspius rapax_, to 0.57 for pike-perch _Lucioperca sandra_. Fish from the Danube River contained an average of 0.59 mg Hg/kg wet wt; fish from all other sites contained $<$ 0.50 mg Hg/kg wet wt.

2336. Gibson, V.R. and G.D. Grice. 1977. Response of macro-zooplankton populations to copper: controlled ecosystem pollution experiment. Bull. Marine Science 27:85-91.

Fluctuations in planktonic abundance and species composition of coelenterates, ctenophores, annelids, crustaceans, molluscs, chaetognaths, phoronids, echinoderms, tunicates, and fish in Controlled Experimental Ecosystems (CEE) were studied in copper concentrations of 0.005, 0.01, and 0.05 mg/l. Abundance of zooplankton was reduced by 82 to 99% in all CEE's, including controls. A portion of the population decline was attributed to grazing by carnivorous ctenophores and medusae, making it difficult to quantitatively assess Cu effects. Abundance of ctenophores and medusae remained at 150-400/m^3 in controls, while falling below 100/m^3 after 22 days in 0.005 mg Cu/l, indicating that these organisms are adversely affected by Cu concentrations tested. At 0.05 mg Cu/l, Pseudocalanus sp. and Acartia longiremis were reduced to 50% of their original numbers 3-3.5X faster than in controls. Results in 0.005 and 0.01 mg Cu/l were more variable and less significant. It is not known whether these effects were the direct result of Cu on the organisms, or an indirect result of alterations at lower trophic levels.

2337. Giesy, J.P., Jr., G.J. Leversee and D.R. Williams. 1977. Effects of naturally occurring aquatic organic fractions on cadmium toxicity to Simocephalus serrulatus (Daphnidae) and Gambusia affinis (Poeciliidae). Water Research 11:1013-1020.

Cadmium toxicity to daphnids and teleosts in soft well water containing various sized organic fractions isolated from pond water was determined, and compared to Cd binding capacity of each water type. Cadmium was bound by Skinface Pond water and by organic fractions isolated from Skinface Pond water, reducing amount of free Cd^{2+} as determined by Cd selective ion electrode. Cadmium was toxic to both S. serrulatus and G. affinis. The LC-50 (48 hr) in well water for S. serrulatus was 7.0 ug/l. Cadmium binding capacities of soft highly organic waters studied here were sufficienty great to affect acute Cd toxicity to S. serrulatus but not G. affinis. The three larger organic fractions isolated from Skinface Pond water reduced Cd toxicity to S. serrulatus, while the smallest fraction slightly increased toxicity though it exhibited greatest binding capacity. Cadmium LC-50 values for S. serrulatus and G. affinis could not be predicted from Cd binding capacities. While Cd binding capacity has little effect on acute toxicity of Cd to G. affinis, it may have greater effect on chronic Cd toxicity and Cd uptake by fish.

2338. Giesy, J.P., Jr. and J.G. Wiener. 1977. Frequency distributions of trace metal concentrations in five freshwater fishes. Trans. Amer. Fish. Soc. 106:393-403.

Whole body concentrations of Cd, Cr, Cu, Fe, and Zn were determined for samples of chain pickerel *Esox niger*, bluegill *Lepomis macrochirus*, blueback herring *Alosa aestivalis*, brook silverside *Labidesthes sicculus*, and golden shiner *Notemigonus crysoleucas* collected near Aiken, North Carolina. Mean concentrations of Cd ranged from 0.08 to 0.29 mg/kg dry wt for the five species, Cr from 0.09 to 0.28 mg/kg, Cu from 1.84 to 5.56 mg/kg, Fe from 130.9 to 149.3 with a low of 39.9 mg/kg in pickerel, and Zn from 101.8 to 232.9 mg/kg dry wt. Species differences in mean concentrations of each metal were compared to normal, lognormal, Weiball, and exponential distributions. Authors concluded that in most cases either the normal distribution, as exhibited by the known required elements Cu, Fe, and Zn, or lognormal, as shown by Cd and Cr, may be satisfactorily employed as statistical models of frequency distributions of trace metal levels in fish.

2339. Gillespie, R., T. Reisine, and E.J. Massaro. 1977. Cadmium uptake by the crayfish, *Orconectes propinquus propinquus* (Girard). Environ. Research 13:364-368.

Freshwater crayfish were exposed at 11 C to 10, 100, and 1000 ug/l Cd containing 0.09 uCi/l Cd-109 for 1, 4, 10, 22, 46, 94, and 190 hrs. At 10 ug/l, whole body Cd residues up to 94 hrs were essentially the same. By 190 hrs, crayfish in the 10 ug/l group had accumulated 18.4 mg/kg Cd wet wt, which was significantly higher than concentrations accumulated during shorter exposures. At 100 ug/l, Cd uptake at 1 hr was significantly lower than groups exposed for 22-190 hrs; uptake at 4.5 hrs was less than the 94 and 190 hr groups; and uptake in the 10 hour exposure group was less than the 190 hr group. At 1000 ug/l uptake increased with time and was significantly greater at every time interval monitored; by 190 hrs, these crustaceans had accumulated a mean Cd concentration of 534 mg/kg. For all time intervals at 1000 ug/l, Cd uptake was significantly higher than the 100 and 10 ug/l concentrations; uptakes at 100 and 10 ug/l were not significantly different.

2340. Coering, J.J., D. Boisseau, and A. Hattori. 1977. Effects of copper on silicic acid uptake by a marine phytoplankton population: controlled ecosystem pollution experiment. Bull. Marine Science 27:58-65.

Effect of added copper concentrations of 0.0025, 0.005, 0.010, or 0.025 mg/l, for 1 to 6 days on silicic acid uptake by natural populations of phytoplankton was studied. In general, Cu inhibited uptake. At 25 mg Cu/l, uptake ranged from 49-98% of control values, with a mean of 60%. Rates of Si-30 $(OH)_4$ uptake were 0.0039-0.0055 mg atoms Si/l/24 hr for controls, and decreased to 0.0009-0.0015 as Cu concentrations increased to 0.025 mg/l. Estimated rates of dissolution of silica from phytoplankton cell walls in the presence or absence of Cu were low, implying that exposure of siliceous phytoplankton to Cu (up to 0.025 mg/l) does not significantly alter dissolution rates.

2341. Gould, E. and J.J. Karolus. 1974. Physiological response of the cunner, Tautogolabrus adspersus, to cadmium. V. observations on the biochemistry. In: U.S. Dept. Comm., NOAA Tech. Rep. NMFS SSRF-681:21-25.

Aspartate aminotransferase activity in liver from cunner, a marine teleost, exposed to 3 and to 24 mg/l Cd for 96 hr was 71% and 59%, respectively, of control values. Fish exposed for 96 hr to 24 mg Cd/l required 20 mM magnesium to activate nicotinamide-adenine dinucleotide; for controls 2 mM was required. Authors suggest that a possible metal-complexing group of proteins in serum of cadmium-exposed cunners warrants further electrophoretic study.

2342. Gould, E. and J.R. MacInnes. 1977. Short-term effects of two silver salts on tissue respiration and enzyme activity in the cunner (Tautogolabrus adspersus). Bull. Environ. Contamin. Toxicol. 18:401-408.

Oxygen consumption in the marine teleost T. adspersus decreased from control rate of 810 ml O_2/h/kg dry wt gill tissue to 637 and 599 when exposed to 0.5 mg silver/l as $AgNO_3$ and $AgC_2H_3O_2$, respectively, for 96 hrs in 24 o/oo S at 22 C. Enzyme activity of aspartate aminotransferase in liver of cunner decreased to 226 umoles NADH oxidized/min/mg protein in 0.5 mg $AgNO_3$/l for 96 hrs, and increased to 273 in 0.5 mg $AgC_2H_3O_2$/l. Neither value was significantly different from controls at 252. Glucose-6-phosphate dehydrogenase activity in liver decreased to 125 umoles NADP reduced/min/mg protein in 0.5

mg $AgC_3H_2O_3$/l for 96 hrs, and dropped significantly to 104 in 0.5 mg $AgNO_3$/l, from control activity of 140. Pyruvate kinase-activity in cunner skeletal muscle was inhibited by 0.004 mg/l cadmium chloride by 12.5% in controls, 19.1% in fish exposed to 0.5 mg $AgNO_3$/l for 96 hrs, and 18.6% in fish exposed to 0.5 mg $AgC_2H_3O_2$/l.

2343. Greig, R.A., A. Adams, and D.R. Wenzloff. 1977. Trace metal content of plankton and zooplankton collected from the New York Bight and Long Island Sound. Bull. Environ. Contamin. Toxicol. 18:3-8.

Nineteen collecting stations in the New York Bight contained major percentages of comb jellyfish, rock crabs, shrimp, or red hake in zooplankton collections. Trace metal concentrations in zooplankton from these stations ranged from <0.5 to 1.4 mg/kg dry wt for Ag, 1.2 to 2.6 for Cd, <3.3 to 35.2 for Cr, <1.6 to 54.4 for Cu, 1.7 to 4.6 for Ni, 10.1 to 81.0 for Pb, and 9.9 to 625.0 for Zn. Concentrations, in mg/kg dry wt, of trace metals in plankton from 11 stations in Long Island Sound ranged from 0.5 to 0.7 for Ag, 1.5 to 1.8 for Cd, <1.1 to 4.7 for Cr, <2.0 to 39.3 for Cu, 0.9 to 4.5 for Ni, 11.1 to 22.6 for Pb, and 7.1 to 136.0 for Zn. Only one sample was speciated, and this consisted mainly of copepods.

2344. Greig, R.A., A.E. Adams and B.A. Nelson. 1974. Physiological response of the cunner, *Tautogolabrus adspersus*, to cadmium. II. uptake of cadmium by organs and tissues. *In*: U.S. Dept. Comm., NOAA Tech. Rep. NMFS SSRF-681:5-9.

Uptake and clearance data were obtained on a marine fish exposed to various concentrations of cadmium as $CdCl_2 \cdot 2\frac{1}{2}$ H_2O in artificial seawater. In the uptake study, cunners were exposed to 0, 3, 6, 12, 24 and 48 mg/l cadmium for 96 hrs. Liver cadmium levels, in mg/kg dry wt, at the above concentrations were 5, 54, 119, 198, 390 and 761, respectively. Cadmium values in gill tissue were 5, 16, 17, 31, 66, and 171, respectively. Mean cadmium residues were 8.2 times higher in liver than gill. Cadmium, in mg/kg wet wt, from organs and tissues of cunners after exposure for 96 hrs to 24 mg Cd/l (and one month post-treatment in natural seawater) were: 0.17 (0.12) in flesh; 8.1 (3.5) in gill; 6.6 (1.8) in red blood cells; 5.9 (1.5) in serum; and 4.8 (3.5) in carcass. Cadmium in liver immediately after exposure ranged from 30 to 117 mg/kg wet wt; those held one month in flowing seawater after exposure, had 5 to 11 mg/kg (3 fish) or 62 to 155 mg/kg (4 fish).

2345. Greig, R.A. and D.R. Wenzloff. 1977. Trace metals in finfish from the New York Bight and Long Island Sound. Marine Poll. Bull. 8:198-200.

Metal concentrations in livers of the teleosts Urophycis chuss, U. tenuis, Pseudopleuronectes americanus, Limanda ferruginea, and the elasmobranch Mustelus canis, caught in the New York Bight and Long Island Sound from April 1971 to December 1973 were as follows: 0.06 to 0.80 mg/kg wet wt for Ag; 0.09 to 0.40 for Cd; <0.1 to 0.5 for Cr; 0.6 to 13.8 for Cu; <0.03 to 0.17 for Hg; 0.03 to 2.5 for Mn; <0.2 to 1.7 for Ni; <0.2 to 1.2 for Pb; and 15.0 to 45.0 for Zn with a low of 3.2 in Mustelus. Concentrations of metals in muscle were generally lower, but followed the same trend between fish and between sites. Trace metal contents were similar for the various species examined, except Zn in dogfish; single species also had similar values at different catch locations. These levels agree with previous data on North Atlantic fish.

2346. Gromov, V.V. 1976. Studies on the sorption of iron group elements from seawater by the radiotracer method. Jour. Radioanal. Chem. 30:181-195.

Methods of radioactive labelling seawater and conditions for reaching the equivalent of physico-chemical states of radiotracers and corresponding stable nuclides in seawater are discussed. Bioassimilation, the uptake and release by plankton, is considered as the way of fast stabilization of physico-chemical forms of radiotracers in the medium, as shown with Co-60, Pu-239, Ru-106, and Tc-99. Sorption of iron, cobalt, nickel, and manganese by the typical ocean bottom sediments of deep-water red clay, diatomic ooze, and carbonate deposit is also analyzed.

2347. Gupta, A.S. 1977. Calcium storage and distribution in the digestive gland of Bensonia monticola (Gastropoda:Pulmonata): a histological study. Biol. Bull. 153:369-376.

Calcium in the pulmonate is found in two principal locations, calcium cells in the acini where Ca is bound to acid mucopolysaccharides as spherites, and in calcium distributing cells surrounding blood vessles, where it is unbound, granular, and labile. It appears that the latter cells extrude Ca directly into blood vessels. Author suggests that the two cell types are responsible respectively for fulfilling slow, long-term needs and rapid, immediate demands, as a system of blood Ca regulation.

2348. Guth, D.J., H.D. Blankespoor and J. Cairns, Jr. 1977. Potentiation of zinc stress caused by parasitic infection of snails. Hydrobiologia 55:225-229.

The influence of two species of digenetic trematode parasites, *Schistosomatium douthitti* and *Trichobilharzia* sp., on tolerance of the gastropod *Lymnaea stagnalis* to 24 and 75 mg/l of zinc (acutely lethal concentrations) was investigated. LC-50 values for *Lymnaea*, in mg/l, were 64 (6 hr); 10 (14 hr); 6.7 (24 hr) and 5.6 mg/l at 48 hrs. Significant reduction in tolerance to zinc occurred for snails with patent infections at both zinc concentrations tested. Snails parasitized with *Trichobilharzia* sp. showed the greater effect.

2349. Guthrie, R.K., F.L. Singleton and D.S. Cherry. 1977. Aquatic bacterial populations and heavy metals-II. influence of chemical content of aquatic environments on bacterial uptake of chemical elements. Water Research 11:643-646.

Bacillus sp., *Sarcina* sp., *Achromobacter* sp., *Flavobacterium* sp., *Brevibacterium* sp., *Chromobacterium* sp., *Pseudomonas* sp., *Azotobacter* sp., and *Streptomyces* sp. from a coal ash basin, a brackish lake and a freshwater lake were isolated and analyzed for elemental composition under the influence of mercury or copper addition. Elemental uptake in mg/kg wet wt of bacterial cells in brackish water of salinity 9.0 o/oo at 25 C with copper or mercury addition was significantly higher for all elements as indicated in the following table.

	Bacterial cells - uptake mg/kg wet wt			
	Water, mg/l	Control	Cu added (2 mg/l)	Hg added (0.04 mg/l)
Co	0.04	0.04	0.2	0.08
Cr	0.4	0.1	0.7	0.3

Cu	1.2	>1.4	4.0	3.4
Fe	16.0	>48.0	162.0	100.0
Hg	0.008	>0.08	0.02	0.2
Mn	0.09	0.3	2.2	1.0
Zn	0.5	>0.8	9.5	18.0
Light metals				
Al-Si	13.0	>18.6	43.0	27.7
Mg	6.2	>6.3	13.3	40.8
Ti	1.1	>8.3	29.0	11.0
Active metals				
Ca	21.8	16.1	18.8	18.5
K	9.7	>13.8	21.0	23.0
Na	19.0	13.6	40.0	22.0

Mercury addition was associated with a greater increase in metal uptake by bacteria than copper addition to brackish water and ash basin water; however the reverse was true of freshwater. Effects were less pronounced in ash basin water and freshwater. Results indicate that elemental uptake by bacteria is influenced by particular combinations of metals in an aquatic source.

2350. Gutknecht, J. 1961. Mechanism of radioactive zinc uptake by Ulva lactuca. Limnol. Oceanogr. 6:426-431.

Effects of metabolism, pH, carrier ions, and temperature upon uptake and accumulation of zinc-65 by the marine algae Ulva lactuca from seawater in light and dark were investigated. Uptake of Zn-65 decreased with decreasing light intensity. The compensation point was at 80 ft-c, with uptake slightly greater than in the dark. At 2 C, Zn-65 accumulation in live Ulva was <1000 counts/min/cm^3 over 24 hrs, while at 22 C, the value was almost 4000. Dead Ulva at 22 C accumulated Zn-65 more rapidly during the first 6 hrs than live Ulva. When photosynthesis was inhibited by 10^{-3}M phenylurethane, zinc uptake was also inhibited. Uptake by living specimens decreased as pH decreased from 9 to 7 at 22.5 C. Maximum accumulation was after 15 hrs in pH 9 in presence of light. When Ulva were killed, uptake increased drastically, regardless of available light or pH. Author suggests that the physical process of adsorption or cation exchange is primarily responsible for Zn-65 uptake. The relationship between photosynthesis and Zn absorption is primarily a secondary effect related to surface/volume ratio and pH.

2351. Hale, J.G. 1977. Toxicity of metal mining wastes. Bull. Environ. Contamin. Toxicol. 17:66-73.

Upstream from the confluence of a mine effluent in South Dakota, Whitewood Creek contained the following concentrations of heavy metals in mg/l: <0.01-0.01 for As, <0.002-0.005 for Cd, <0.01-0.03 for Cr, <0.03 for Cu, <0.05 for Pb, 0.0006-0.002 for Hg, <0.01-0.02 for Ni, <0.01 for Ag, and <0.004-0.05 for Zn. Toxicity of these metals, using pricipally nitrate forms, to 2-month-old rainbow trout in Whitewood Creek water was tested in continuous flow bioassays using a mobile unit. LC-50 (96 hr) values, in mg/l, were 10.8 for As, 0.007 for Cd, 24.1 for Cr, 0.25 for Cu, 8.0 for Pb, 0.03 for Hg, 35.5 for Ni, 0.029 for Ag, and 0.55 for Zn. Author suggests that metal concentrations in Whitewood Creek water may act additively in combination with test concentrations to produce artificially low LC values.

2352. Hall, A.S., F.M. Teeny and E.J. Gauglitz, Jr. 1976. Mercury in fish and shellfish of the northeast Pacific. II. sablefish, Anoplopoma fimbria. U.S. Dept. Comm., NOAA Fish. Bull. 74:791-799.

Mean mercury levels, in mg/kg wet wt, of decapitated, eviscerated sable fish from various geographic locations were 0.04 from the Bering Sea, 0.28 southeast Alaska, 0.37 Washington State, 0.40 Oregon, 0.26 northern California, 0.47 central California, and 0.60 in southern California. Mercury levels in this species showed a gradual increase in magnitude from north to south; the average length of sablefish decreased from north to south. Approximately 30% of the 692 specimens exceeded the U.S. Food and Drug Administration action level of 0.50 mg Hg/kg wet wt. A positive correlation between fish size and mercury content was observed.

2353. Hall, A.S., F.M. Teeny, L.G. Lewis, W.H. Hardman and E.J. Gauglitz, Jr. 1976. Mercury in fish and shellfish of the northeast Pacific. I. Pacific halibut, Hippoglossus stenolepis. U.S. Dept. Comm., NOAA Fish. Bull. 74:783-789.

Muscle from 1,227 halibut were analyzed for mercury. The mean mercury concentration in mg/kg wet wt from five geographic locations was: 0.15 Bering Sea; 0.20 Gulf of Alaska; 0.26 southeast Alaska; 0.32 British Columbia; and 0.45 from

Washington-Oregon. Mercury was uniformly distributed from nape to tail in edible muscle. Within each geographic area Hg concentration increased with fish size. Mercury concentration also increased in fish of the same size from the northern to the southern part of the species range.

2354. Hamdy, M.K., O.R. Noyes, and S.R. Wheeler. 1977. Effect of mercury on bacteria: protection and transmethylation. In: Drucker, H. and R.E. Wildung (eds.). Biological implications of metals in the environment. ERDA Symp. Ser. 42: 20-35. Avail. as CONF-750929 from Nat. Tech. Inf. Serv., U.S. Dept. Comm., Springfield, VA. 22161

Seven genera of bacteria, from three different sediments, were screened for mercury resistance. Bactericidal levels of $HgCl_2$ over 48 hrs were 500 mg Hg/l for Bacillus, 400 for Escherichia, 150 for Staphylococcus, 60 for Streptococcus, 1.1 for Bacteriodes, and 1.0 for Clostridium. Minimum lethal concentrations were 1200 mg Hg/l for resistant strains of Enterobacter aerogenes after adaptation by serial dilution, but only 50 mg/l for sensitive strains. The resistant culture produced methylmercury from $HgCl_2$ under both aerated and unaerated conditions; production was cyclic and decreased with DL-homocysteine but increased with methylcobalamin. Authors suggest methylmercury production is a mechanism by which inorganic Hg is detoxified and secreted into the environment. One Bacteriodes culture exposed to 10 mg Hg/l showed that 2.5 or 5.0 mg dry wt of sediment protected bacterial cells against Hg toxicity. This effect was probably due to presence of organic matter since ashed sediment afforded no protection. Sediment may, therefore, protect aquatic bacterial communities from deleterious effects of mercury.

2355. Hand, S.C. and W.B. Stickle. 1977. Effects of tidal fluctuations of salinity on pericardial fluid composition of the American osyter Crassostrea virginica. Marine Biology 42:259-272.

Oysters were subjected to simulated tidal fluctuations of salinity of 20-10-20 o/oo, 15-10-15 o/oo, and 10-5-10 o/oo during 24.8 hr patterns. Pericardial fluid Mg^{2+} was hyperionic by as much as 3 mM as ambient water salinity decreased during the cycle, and then became slightly hypoionic as salinity increased. Under a 2-week diurnal fluctuation pattern between 20 and 10 o/oo S, pericardial fluid Mg^{2+} became more intermediate between high and low salinity values after day 5. Osmolarity, Na^+, Cl^-, and Ca^{2+} followed similar patterns in all experiments, while K^+ levels did not follow ambient seawater as closely. The ionic composition of dilution water had little effect on the osmotic or ionic response of the osyter's pericardial fluid. Ninhydrin-positive substances in oysters and percent body water varied inversely with salinity. Solute movement accounted for most of the change in pericardial fluid osmolarity. During 20-10-20 o/oo cycles, oyster valves stayed open 56% of the time. However, when salinity changed abruptly from 20 to 10 o/oo, valves closed within 5 min and stayed closed for 19 hrs.

2356. Harding, J.P.C. and B.A. Whitton. 1977. Environmental factors reducing the toxicity of zinc to *Stigeoclonium tenue*. British Phycol. Jour. 12:17-21.

Influence of pH, Mg, Ca, and P on toxicity of zinc to the freshwater algae *S. tenue* was shown to differ between a Zn tolerant population and one that was sensitive. Tolerance Index Concentration (T.I.C.) of zinc of the sensitive population increased from 0.6 to 0.7 mg Zn/l as pH rose from 7.1 to 7.6 in 1.0 mg Ca/l, and increased from 0.9 to 1.0 mg/l as pH rose in 10.0 mg Ca/l. Tolerance by this population also increased to slightly above 1.0 mg Zn/l as Mg rose to 299 mg/l and PO_4-P rose to 30 mg/l, and increased to 2.0 mg Zn/l as Ca rose to 200 mg/l. More pronounced differences were seen with the Zn tolerant population. T.I.C. increased from 3.4 to 11.0 mg Zn/l as pH rose from 6.6 to 7.6 in 1.0 mg Ca/l, and increased from 7.8 to 14.1 mg/l as pH rose in 10.0 mg Ca/l. When Mg and Ca levels approached 200 mg/l, tolerance by algae increased from <1.0 to 20.0 mg Zn/l; and increased from about 5.0 to 20.0 mg Zn/l as PO_4-P rose to 30 mg/l.

2357. Harrison, P.J., H.L. Conway, R.W. Holmes, and C.O. Davis. 1977. Marine diatoms grown in chemostats under silicate or ammonium limitation. III. cellular chemical composition and morphology of *Chaetoceros debilis*, *Skeletonema costatum*, and *Thalassiosira gravida*. Marine Biology 43:19-31.

S. costatum, *C. debilis*, and *T. gravida* were grown under no limitation and ammonium or silicate limitation or starvation. Changes in cell morphology were correlated with observed changes in chemical composition. Cultures grown under silicate starvation or limitation showed a decrease in particulate silica, from 0.8 x 10^{-7} ug-at/l/cell in non-limited cells for *S. costatum*, to 0.7 x 10^{-7} (starvation) and 0.4 x 10^{-7} (limitation). For *C. debilis*, Si dropped from 3.0 x 10^{-7} to 2.3 x 10^{-7} (starvation) and 1.1 x 10^{-7} (limitation) and from 20.0 x 10^{-7} to 10.8 x 10^{-7} and 12.8 x 10^{-7} for *T. gravida*. Particulate carbon, nitrogen, phosphorus, and chlorophyll *a* increased in diatoms. The most sensitive indicator of silicate limitation or starvation was the ratio C:Si, being 3 to 5X higher than values for non-limited cells. The ratios Si:chlorophyll *a*, and Si:P were lower and N:Si higher than non-limited cells by a factor of 2 to 3. Ammonia-starved and NH_4-limited cells contained 0.7 and 0.8 x 10^{-7} ug-at Si/l per cell, respectively, for *S. costatum*, 3.0 and 2.7 x 10^{-9} for *C. debilis*, and 16.3 and 13.4 for *T. gravida*. NH_4-starved cells also contained more chlorophyll *a*, C, N, and P per cell volumes than NH_4-limited cells. N:Si was the most sensitive ratio for ammonium limitation or starvation, being 2 to 3X lower than non-limited cells. Limited cells had less of the limiting nutrient per unit cell volume than starved cells and more of the non-limiting nutrients, *i.e* silica and phosphorus for NH_4-limited cells. This suggests that nutrient-limited cells rather than nutrient-starved cells should be used along with non-limited cells to measure the full range of potential change in cellular chemical composition for species under nutrient limitation.

2358. Harrison, W.G. and J.M. Davies. 1977. Nitrogen cycling in a marine planktonic food chain: nitrogen fluxes through the principal components and the effects of adding copper. Marine Biology 43:299-306.

Nitrogen cycling in a natural planktonic food chain (seston, copepods, ctenophores) was followed before and after perturbation by 10 ug/l of copper. Changes attributed to "copper effects" were: more pronounced initial decrease in seston-N after copper addition, followed by elevated settling rates and more pronounced subsequent recovery of seston-N; significantly more rapid decrease in zooplankton stocks, essentially disappearing by the third week after copper addition; inhibition of nitrate-specific assimilation rate during the first week after copper addition; inhibition of zooplankton grazing. Since zooplankton stocks and fluxes were most drastically affected by copper, its overall effect on N-cyclying through the planktonic food chain would depend largely upon the importance of zooplankton in regulating the production of the remaining seston.

2359. Harrison, W.G., R.W. Eppley, and E.H. Renger. 1977. Phytoplankton nitrogen metabolism, nitrogen budgets, and observations on copper toxicity: controlled ecosystem pollution experiment. Bull. Marine Science 27:44-57.

In 0.005 mg/l copper, assimilation rate of NO_3 in phytoplankton in the top 9 meters was reduced to 0.003-0.033 umoles N/l/hr, from control values of 0.01-0.09. In 0.01 mg Cu/l the rate was 0.006-0.017 umole N/l/hr, and in 0.05 the rate was 0.001-0.003. Assimilation rates of NH_4 declined from control values of 0.007-0.055 umoles N/l/hr to 0.02-0.03, 0.008-0.013, and 0.004-0.010 in the three respective Cu concentrations. After 2-3 days, nitrate assimilation decreased to 0.5 x 10^3/hr in 0.05 mg Cu/l and to 0.6 in 0.005 mg Cu/l from control values of 6.2-13.0. Ammonium assimilation rate decreased only to 5.2 x 10^3/hr from controls of 8.3 in 0.005 mg Cu/l for 3 days. Photosynthetic C assimilation and synthesis of nitrate reductase were inhibited and cell disruption and loss of accumulated NH_4 were seen in *Noctiluca* sp. in Cu treated seawater. Evidence suggests that addition of copper to enclosures resulted in acute inhibition of phytoplankton growth and a replacement of the initial phytoplankton by a copper-tolerant assemblage. Bioassay experiments indicated that even after shifts to copper-tolerant forms, copper in enclosures remained in a chemical form still toxic to phytoplankton and that degree of copper-tolerance of phytoplankton was related to ambient copper concentrations.

2360. Hewett, C.J. and D.F. Jefferies. 1976. The accumulation of radioactive caesium from water by the brown trout (*Salmo trutta*) and its comparison with plaice and rays. Jour. Fish Biology 9:479-489.

Patterns of accumulation of Cs-137 from water by tissue and organs of trout are described. The ratio of Cs-137 in fish/g to Cs-137 in water/g after exposure for 420 days in Cs-137 solutions were 1.9 in blood cells; 0.31 in blood serum; 5.7 in liver; 8.9 in gut; 5.7 in kidney; 5.2 in gill; 2.8 in skin; 8.0 in muscle; and 4.2 in bone. In all tissues and organs examined, other than muscle, the rate processes of trout were intermediate between plaice, a flounder-like fish, and ray, an elasmobranch. It is concluded that most of the cesium accumulated by trout from water enters other than by gut, probably through gills; but as with plaice and ray, the main source of cesium, possibly 90%, comes from food. Despite differences in levels of accumulation, the ratios of tissue to blood steady state concentrations are very similar in all three species. The steady state cesium concentration of blood appears to be directly related to red blood cell count of the fish.

2361. Hodson, P.V. 1976. δ -amino levulinic acid dehydratase activity of fish blood as an indicator of a harmful exposure to lead. Jour. Fish. Res. Bd. Canada 33:268-271.

Activity of red cell δ-amino levulinic acid dehydratase (ALA-D) of rainbow trout was depressed after exposure to lead; the effect increased with both lead concentration and exposure time. At 143 ug Pb/l ALA-D activity declined 50% after 1 week and 74% after 16 weeks. At 23 ug Pb/l, ALA-D activity dropped sharply after 2 weeks but returned to normal after 4 weeks. The lowest lead concentration tested, 13 ug/l, caused significant inhibition after 4 weeks, with 40% reduction after 16 weeks. Assays of ALA-D activity may provide a short-term indication of long-term harmful effects of lead.

2362. Hodson, P.V., B.R. Blunt, D.J. Spry and K. Austen. 1977. Evaluation of erythrocyte δ-amino levulinic acid dehydratase activity as a short-term indicator in fish of a harmful exposure to lead. Jour. Fish. Res. Bd Canada 34:501-508.

The activity of erythrocyte δ-amino levulinic acid dehydratase (ALA-D) of fish is easily measured under a variety of experimental conditions. Exposure of rainbow trout Salmo gairdneri, brook trout Salvelinus fontinalis, goldfish Carassius auratus, and pumpkinseeds Lepomis gibbosus to Pb consistently inhibited ALA-D within 2 wks at concentrations as low as 10, 90, 470, and 90 ug/l, respectively. In rainbow and brook trout these concentrations were closely related to the published minimum effective concentrations causing sublethal harm. Blood lead concentrations ranged from 30-600 ug/l in controls and up to 5400 ug/l in treated fish. There were significant negative correlations between 1) ALA-D activity and log of blood Pb concentration and 2) ALA-D activity and log of Pb in water. A positive correlation between blood Pb and water Pb is shown. Near lethal exposures to cadmium, copper, zinc, and mercury did not significantly inhibit ALA-D activity. Recovery of ALA-D activity of rainbow trout after transfer from 120 ug/l lead to clean water occurred in 8 weeks. This enzyme provides fast, consistent, specific, and sensitive estimates of lead concentrations causing sublethal harm to fish and may help to relate sources of lead to degree of exposure of fish populations in the field.

2363. Hoppenheit, M. and K.-R. Sperling. 1977. On the dynamics of exploited populations of Tisbe holothuriae (Copepoda, Harpacticoidae) IV. the toxicity of cadmium: response to lethal exposure. Helgol. wiss. Meeresunters. 29:328-336.

Adult copepods and nauplii were exposed to 0.148, 0.222, 0.333, 0.500, 0.750 or 1.125 mg Cd/l, with weekly exploitation rates of 10, 30, 50, 70, or 90%, under conditions of surplus food, 22 C, and 30 o/oo S. All populations exposed to 0.500 mg/l or higher, and 20% exposed to 0.333 mg/l, died within 3 to 9 weeks. Copepods in lower concentrations survived the experimental exposure period of 30 weeks. Authors found no relation betwen survival and exploitation rates. Significant numbers of dead copepods were detected in sampling regimes of 5 times per week but not in weekly samples due to rapid decomposition and cannibalism.

2364. Hoss, D.E., L.C. Coston, J.P. Baptist and D.W. Engel. 1975. Effects of temperature, copper and chlorine on fish during simulated entrainment in powerplant condenser cooling systems. In: Environmental effects of cooling systems at nuclear power plants. IAEA-SM-187/19 Inter. Atom. Ener. Agen. Vienna, Austria: 519-527.

Conditions of entrainment were simulated in the laboratory to investigate effects of thermal shock, combined effects of thermal shock and copper, and combined effects of thermal shock and chlorine on survival of larval fish. Survival of larval pinfish, Lagodon rhomboides, held for 24 h in water containing 1.0 mg/l copper prior to thermal shock was significantly reduced at shock temperatures of 12 and 15 C above acclimation temperatures. Salinity did not significantly affect survival.

2365. Howard, H.H. and S.W. Chisholm. 1975. Seasonal variation of manganese in a eutrophic lake. Amer. Midland Natural. 93:188-197.

Manganese at one m strata was monitored for 15 months in a small, dimictic eutrophic lake near Saratoga Springs, N.Y. Concentrations were lowest in surface strata, 0.01-0.11 mg/l, and highest in anaerobic bottom waters, 0.04-2.49 mg/l. Levels in bottom waters consistently increased after stratification until a maximum was reached just before overturn. Overturn markedly raised Mn concentrations at the surface for a period of 6-12 weeks. Manganese particles smaller than 0.45 u accounted for almost all of the Mn found in anaerobic water but only 0-13% in aerobic water. Total Mn varied from 170 kg minimum, after spring overturn, to 2550 kg at the end of summer stratification. Possible effects of Mn cycling on algae are discussed.

2366. Howard-Williams, C. and W.J. Junk. 1977. The chemical composition of Central Amazonian aquatic macrophytes with special reference to their role in the ecosystem. Arch. Hydrobiologie 79:446-464.

Mineral content of 27 species of aquatic macrophytes collected from lakes in the Central Amazon region was determined. Sodium levels in free floating species averaged from 400 to 16,600 mg/kg dry mass, in plants rooted in floating mats 200 to 2,700, and in sediment-rooted plants 100 to 16,600 mg/kg. Average concentrations, in mg/kg dry mass, for potassium were 17,800 to 56,900 (free-floating), 16,600 to 36,900 (mats), and 850 to 33,300 (rooted); for magnesium it was 1,600 to 7,900 (floating), 900 to 4,600 (mats) and 700 to 4,400 (rooted); for calcium these values were 5,200 to 42,800 (floating), 2,300 to 14,200 (mats) and 1,500 to 14,800 (rooted); and for silicon 1,300 to 28,400, 2,600 to 28,700 and 1,800 to 37,200, respectively. P and K were high compared to values in soils and waters in the area, while Ca was low. Measurements were also taken for nitrogen, phosphorus, ash, dry matter, polyphenols, potential energy, and cell wall material. Aquatic plants of the area may act as nutrient reservoirs in water bodies and play a major role in biogeochemical cycling in Amazonian aquatic ecosystems.

2367. Hughes, G.M. and R.J. Adeney. 1977. The effects of zinc on the cardiac and ventilatory rhythms of rainbow trout (Salmo gairdneri, Richardson) and their responses to environmental hypoxia. Water Research 11:1069-1077.

Recordings were made of trout cardiac and ventilatory rhythms during exposure to 40 and 10 mg/l zinc. Exposure to 40 mg Zn/l for at least 12 hours produces increases in ventilatory and coughing frequency rates and a decrease in heart rate; the percentage coupling between the two rhythms usually increased. At 10 mg Zn/l effects are not as apparent. Exposure for 4 hours to 10 mg Zn/l modifies the response of trout to hypoxia by decreasing both the degree of bradycardia and increase in ventilation usually associated with lowering of ambient oxygen tension. Authors concluded that zinc interferes with mechanisms involved in uptake of oxygen at the gills and consequently can alter ability of trout to respond to the additional stress of oxygen deprivation.

2368. Hung, T.-C. and T.-T. Lin. 1976. Study on mercury in the waters, sediments and benthonic organisms along Cahi-I coastal area. Acta Oceanogr. Taiwanica 6:30-38.

Mercury and possible complexing inorganic ligands were analyzed from the Chai-I coastal area in Taiwan including the Potzu and Peikang Rivers during December 1974 to October 1975. Nitric acid, at pH 1.0, was added to preserve mercury in the samples, since concentrations of 0.001 and 0.002 mg Hg/l reduced to almost zero over 30 days without acidification. Hg content in coastal waters averaged 0.08 to 0.43 ug/l; river water averaged 0.12 to 0.72 ug Hg/l. Of the major ligands, [illegible].0 to 82.4% of $HgCl_4^{-2}$ was found in coastal ocean water and 81.3 to 97.5% of HgClOH in Potsu River. Mud and sand sediments contained an average of 0.015 to 0.070 mg Hg/kg. Mercury levels in oysters ranged from 0.01 to 0.05 mg/kg wet wt, with accumulation factors of 70 to 360 over coastal waters. Clams contained 0.01 to 0.03 mg Hg/kg, with accumulation factors of 24 to 225.

2369. Innes, D.J. and L.E. Haley. 1977. Genetic aspects of larval growth under reduced salinity in *Mytilus edulis*. Biol. Bull. 153:312-321.

Growth of mussel larvae at 30 or 18 o/oo salinity for 18 days was not significantly different. Slower growth was observed in 11 and 16 o/oo salinity after 3 and 11 days, respectively. Larvae from these two groups showed no abnormal development or swimming behavior when compared to the 30 o/oo group. When families of known genetic parentage were reared at different salinities, genetic analysis indicated substantial variation in larval length 16 days after fertilization, and genetic interaction with salinity. This is interpreted as the presence of genes influencing larval growth (which are dependent on salinity for expression), and this may be related to a past selective influence of a fluctuating environment.

2370. Ishak, M.M., S.R. Khalil, and W.E.Y. Abdelmalik. 1977. Distribution and tissue retention of cesium-134 and cobalt-60 in the Nile catfish Clarias lazera (Cuv. & Val.) Hydrobiologia 54:41-48.

Nile catfish concentrated Cs-134 and Co-60 from the aquatic environment. Rate of Cs-134 uptake increased with increasing exposure time to a maximum concentration factor of 0.37 in 15 days; for Co-60 the maximum CF of 0.36 occurred after one day. Internal distribution of Cs-134 in fish organs due to uptake from the aquatic environment, in decreasing order, was muscle, bone, gills, stomach, kidneys, intestine, and liver. Concentrations for Co-60, in decreasing order were bone, muscle, gills, intestine, kidney, stomach, and liver. Internal distribution due to ingestion of these radionuclides followed a similar pattern.

2371. Jackim, E., G. Morrison, and R. Steele. 1977. Effects of environmental factors on radiocadmium uptake by four species of marine bivalves. Marine Biology 40:303-308.

Temperature, salinity, bottom-sediment type, and zinc concentration all influence Cd uptake by Mya arenaria, Mytilus edulis, Mulinia lateralis and Nucula proxima. Radiocadmium-109 uptake during short-term exposures differed widely among species. However, for all species increasing temperature or decreasing salinity was associated with increasing uptake. The presence of bottom sediment depresses Cd accumulation in some benthic animals. Zinc, at 0.5 mg/l, substantially decreased Cd uptake by M. edulis and M. lateralis. During exposure for 14 days to 5 ug Cd/l, M. arenaria contained 2.2 mg Cd/kg dry wt at 10 C, and 4.2 at 20 C; M. edulis contained 9.3 and 9.4, respectively; M. lateralis contained 3.6 and 8.9. After exposure to 20 ug Cd/l for 14 days, M. arenaria contained 16.8 mg Cd/kg dry wt at 10 C and 29.0 at 20 C; for M. edulis it was 50.6 and 60.4, respectively; for M. lateralis it was 10.3 and 20.5; and for N. proxima it was 2.0 and 4.6 mg Cd/kg dry wt, respectively.

M. arenaria subjected to 5 ug Cd/l plus tracer for 7 days contained 6111 cpm when no sediment was present in aquaria, 4730 with sand, and 2881 with mud; all treatments were significantly different. *M. lateralis*, under the same respective conditions, showed an average of 2294, 2264, and 1496 cpm, with no significant difference between treatments. When exposed to 2 ug Cd/l plus tracer for 21 days at 10 C, *M. edulis* contained 83 ug Cd/kg dry tissue in 20 o/oo salinity, but only 32 in 30 o/oo S. *M. lateralis* had 52.0 ug Cd/kg dry wt (10 C) and 24 (20 C), respectively, and *N. proxima* had 21.0 and 0.6. Under the same exposure at 20 C, *M. edulis* contained 108 ug Cd/kg dry wt in 20 o/oo salinity and 86 in 30 o/oo S; for *M. lateralis* it was 36 ug Cd/kg wet wt (10 C) and 8 (20 C) respectively; for *N. proxima* this was 5.4 and 2.6. Authors concluded that important species and temperature, salinity, zinc and sediment type should be considered in studies on cadmium accumulations by benthic marine organisms.

2372. Jennings, C.D. 1977. ^{55}Fe in Pacific Ocean plankton. Marine Biology 44:223-226.

Mixed plankton samples, mostly copepods and chaetognaths, collected from a large part of the eastern South Pacific in the vicinity of atmospheric nuclear tests were analyzed for Fe-55. Specific activity of Fe-55 in plankton increased from below detectable limits at 20°N to a maximum of 130 nCi/g Fe at 20°S and then decreased to 5 at 50°S. Along an east-west track near 15°S, a peak of 90 occurred at 135°W. It is suggested that this maximum is the result of fallout from French nuclear tests at Mururoa Atoll (22°S; 139°W). The increase in Fe-55 at high latitudes observed in previous studies in the North Atlantic Ocean and North Pacific Ocean did not occur in the South Pacific Ocean which supports the suggestion that belts of high tropospheric fallout accounted for the increase in northern oceans.

2373. Khobot'yev, V.G., V.I. Kapkov, Y.G. Rukhadze, N.V. Turunina, and N.A. Shidlovskaya. 1976. Algal uptake of copper from compounds and its effect on salt metabolism in algae. Hydrobiological Jour. 12:29-34.

Copper accumulation in the the freshwater algae *Scenedesmus quadricauda* and *Anabaena variabilis* was directly related to algicidial action of the Cu compound tested. Toxicity of Cu was due to the cells' ability to accumulate Cu to a greater degree from compounds such as $[Cu(\beta\text{-Pyc})_2]Cl_2$, with a coordination bond between metal and ligand, than from $CuCl_2$ with an ionic bond, or from $[Cu(\infty\text{-Pyc})_2]$ having a coordinate-covalant bond. Maximum uptake by *Anabaena* was 25,000 mg Cu/kg dry wt in 0.99 mg Cu/l on day 30; for *Scenedesmus* this was 18,000 mg/kg in 4.95 mg Cu/l on day 10. Copper complex concentrations of 0.50 to 4.95 mg/l disturbed salt metabolism in algal cells due to Cu accumulation or K loss; Na and Ca levels remain relatively constant. In 4.95 mg/l of Cu complex, cellular K content decreased by 80% within 30-60 minutes.

2374. Khristoforova, N.K., N.A. Sin'kov, G.N. Saenko, and M.D. Koryakova. 1976. Content of the trace elements Fe, Mn, Ni, Cr, Cu and Zn in the proteins of marine algae. Soviet Jour. Marine Biology 2(2):124-128.

Concentrations of Fe, Mn, Ni, Cr, Cu, and Zn were determined by emission spectroscopy in protein extracts of three species of red algae *Rhodomela laris*, *Polysiphonia japonica*, *Ptilota filicina*, and the brown algae *Agarum cribrosum*. Protein residues contained more than 0.1% Mn, up to 0.085% Fe and up to 0.025 % Zn. Copper levels in proteins from aqueous and saline extracts did not exceed 0.0005-0.0006%. Large quanitites of Mn and Zn were found in the aqueous and saline protein extracts. Alkali-soluble proteins contained chiefly Fe, Ni, Cr, and Cu. Metal content of all algal species in mg/kg dry wt were 248 to 954 for Fe, 139 to 825 for Mn, 10 to 12 for Zn, 11 to 25 for Ni, 7 to 13 for Cr, and 1.3 to 5.7 for Cu.

2375. Kidder, G.M. 1977. Pollutant levels in bivalves, a data bibliography. U.S. Environ. Protect. Agenc. Contract No. R-80421501, Avail. from Scripps Inst. Ocean., La Jolla, Calif.

Published information on concentrations of four major pollutant groups in bivalve molluscs, is presented to provide baseline data for present and future studies. The four major catagories of pollutants investigated were metals, pesticides and halogenated hydrocarbons, radionuclides, and petroleum hydrocarbons. Metals listed included Ag, Al, As, Au, Ba, Bi, Ca, Cd, Ce, Co, Cr, Cs, Cu, Eu, Fe, Ga, Ge, Hg, K, La, Li, Mg, Mn, Mo, Na, Nb, Ni, Pb, Po, Pu, Ra, Rb, Ru, Sb, Sc, Se, Si, Sm, Sn, Sr, Tc, Th, Ti, V, Zn, and Zr.

2376. Kim, J.H., E. Birks, and J.F. Heisinger. 1977. Protective action of selenium against mercury in northern creek chubs. Bull. Environ. Contamin. Toxicol. 17: 132-136.

Pretreatment of the freshwater teleost, *Semotilus atromaculatus*, with 3.0 mg/l selenium as selenium dioxide for 48 hrs at 24 C produced higher survival than non-treated groups after exposure to mercuric chloride concentrations for 48 hrs at concentrations up to 0.19 mg Hg/l. Se pretreatment at 3.0 mg/l had no obvious effects upon the fish, but higher concentrations, of 12.0 mg Se/l, were associated with heavy mucous accumulation on gills of survivors and high mortality. At Hg concentrations of 0.01, 0.04, and 0.07 mg/l Se, pretreatment appeared to favor Hg accumulation. At 0.07 mg/l, Hg in pretreated fish was 24.5 mg/kg dry wt and in untreated only 18.6. However, all pretreated fish survived while 30% of the untreated group died. At Hg concentrations of 0.10, 0.13 and 0.16 mg/l, body Hg dropped before rising again in Se pretreated fish and was below the level in untreated specimens. In 0.16 mg Hg/l, both groups had approximately 28.0 mg Hg/kg dry wt.

2377. Kim, K.C., R.C. Chu and G.P. Barron. 1974. Mercury in tissue and lice of northern fur seals. Bull. Environ. Contamin. Toxicol. 11:281-284.

Tissues of nursing cows, newborn and suckling pups of *Callorhinus ursinus*, and their obligate, permanent sucking ectoparasite lice *Antarctophthirus callorhini* and *Proechinophthirus fluctus* were analyzed for mercury. Mean Hg levels in nursing cows, in mg/kg wet wt, were: 4.87 in air dried hair; 0.099 in whole blood; and 0.014 in whole milk. In newborn pups, Hg levels were 3.68 hair, 0.019 blood, and 0.22 in *A. callorhini*. In 2 month old pups, mercury levels were 5.4 hair, 0.069 blood, 0.63 in *A. callorhini* and 0.51 in *P. fluctus*. Presence of mercury in milk could account for the higher mercury content in the 2 month-old pups. Mercury in hair and blood of newborn pups indicates that mercury is able to cross placental membranes. A positive correlation existed between level of mercury in blood and that in hair and in lice. Authors suggest that hair and lice samples show promise for monitoring Hg levels in northern fur seals.

2378. Klein, A.E. 1977. A study of heavy metals in Lake Abbaya, Ethiopia, and the incidence of non-parasitic elephantiasis. Water Research 11:323-325.

Surface water from Lake Abbaya and nearby hot springs contained, in mg/l: 0.05-1.00 As^{3+}; 0.2-16.0 B; 0.002-0.85 Hg; 0.04 Au; 0.002-0.04 Pb; and 0.001-0.47 Cr. No detectable amounts of Zn, Cu, Cd, Ba, or Ag were found. Author suggests that the high incidence of non-parasitic elephantiasis in humans from the lake region may be due to mercury and arsenic contamination.

2379. Kobayashi, N. and K. Fujinaga. 1976. Synergism of inhibiting actions of heavy metals upon the fertilization and development of sea urchin eggs. Science Engin. Rev. Doshisha Univ. 17:54-69. (In Japanese).

Effects of cadmium, copper, nickel, and zinc on sea urchin egg development was determined. After 24 hrs, development was retarded for Hemicentrotus pulcherrimus in 0.08-0.32 mg Cu/l, 0.20-0.82 mg Zn/l, 0.37-1.47 mg Ni/l, and 0.35-1.41 mg Cd/l. After 15 hrs, retardation occurred for Anthocidaris crassispina eggs in 0.16-0.64 mg Cu/l, 0.41-1.64 mg Zn/l, 0.37-1.47 mg Ni/l, and 0.70-2.81 mg Cd/l. Metals induced decreased rates of fertilization, cell division, gastrulation, and occurrence of polyspermy, permanent blastula and exogastrula. Eggs developed normally in 0.04 mg Cu/l, 0.10 Zn, 0.18 Ni, and 0.18 Cd for Hemicentrotus; and in 0.08 mg Cu/l, 0.20 Zn, 0.18 Ni, and 0.35 Cd for Anthocidaris, the more tolerant species. When used at their respective concentrations, strong synergistic actions appeared for mixtures of Cu and Zn and secondarily for Cu-Cd and Zn-Cd. Mixtures of Cu-Ni, Zn-Ni, and Cd-Ni acted additively on eggs from both species of echinoderms.

2380. Koeller, P. and J.R. Parsons. 1977. The growth of young salmonids (Onchorhynchus keta): controlled ecosystem pollution experiment. Bull. Marine Science 27:114-118.

Presence of 0.0025 mg/l inorganic copper, 10X ambient level, for 47 days caused no observable effect on growth or survival of juvenile salmon held at about 30 o/oo salinity. Controlled ecosystems, with no metal added, supported fish growth when large crustacean zooplankton were available, but not when only small zooplankton were present. This suggests that factors (pollutants or natural events) which alter the spectrum of prey items available to young fish may be more important than direct effect of physical or chemical factors on juveniles.

2381. Koli, A.K., W.R. Williams, E.B. McClary, E.L. Wright, and J.M. Burrell. 1977. Mercury levels in freshwater fish of the state of South Carolina. Bull. Environ. Contamin. Toxicol. 17: 82-89.

Samples of fish from rivers, lakes, and ponds in South Carolina collected during the summers of 1974 and 1975 were analyzed for mercury. Mercury, in mg/kg wet wt, in muscle was 0.02-0.07 for redbreast, 0.05-0.11 for white bass, 0.04-0.05 for shad, 0.04-0.12 for bluegill, 0.06-0.09 for catfish, 0.64 for pike, 0.63 for mudfish, 0.49 for warmouth, and 0.53 for largemouth bass. Concentrations increased with increased body weight and at higher levels on the food chain, suggesting bioamplification of Hg up the food chain. Pike from Lake Murray had Hg levels of 0.95 mg/kg wet wt in liver, 0.72 in kidney, 0.64 in muscle, and $<$ 0.33 in other organs; ratio of muscle:liver Hg was 0.67. Hg levels in mudfish from Edisto River were 0.83 mg/kg wet wt in liver, 0.69 in kidney, 0.63 in muscle, and $\leq$ 0.3 in other organs; muscle:liver Hg ratio was 0.76. Authors state that carnivorous and bottom-feeding fishes are the most reliable Hg pollution indicators.

2382. Koyama, J. and Y. Itazawa. 1977. Effects of oral administration of cadmium on fish - I. analytical results of the blood and bones. Bull. Japan. Soc. Sci. Fish. 43:523-526. (In Japanese).

Carp, Cyprinus carpio, were fed diets containing 0.0, 28, 140, 570, 1700, or 5700 mg Cd/kg dry wt for 30 or 60 days. As cadmium content increased, alkaline phosphatase activity of serum decreased and Ca concentration decreased in serum from 100 to 40 mg/l, in vertebrae from 2750 to 2250, in vertebrae ash from 5250 to 4750, and in cranial ash from 3750 to 3500 mg/kg. Inorganic phosphorus concentration of serum increased from 70 to 100 mg/l with increasing Cd in the diet. Violent swimming and tetany were observed in fish fed Cd. This may have been due to hyperexcitability of the nervous system and muscles, which is attributable to low Ca and high inorganic P levels in plasma.

2383. Koyama, J. and Y. Itazawa. 1977. Effects of oral administration of cadmium on fish - II. results of morphological examination. Bull. Japan. Soc. Sci. Fish. 43:527-533. (In Japanese).

As cadmium content increased to 1700 mg/kg in dry food given to carp, weight gain in fish was reduced up to 15%, and weight of hepatopancreas, in relation to whole body weight, generally decreased. Lateral curvature of vertebral column was observed in 13 of 93 fish fed a diet containing ≥ 140 mg Cd/kg; these exhibited violent swimming and tetany. In Cd-exposed fish, abnormal black granules accumulated around blood vessels in the liver, proximal renal tubules exhibited degeneration; and cells seemed to have lost protoplasm. A possible mechanism for lateral curvature of the vertebral column is: degeneration of renal tubules attributable to orally administered Cd produced low Ca and high inorganic P levels of plasma and low Ca of vertebrae. This induced hyperexcitability of the nervous system and muscles, resulting in violent swimming and tetany, lateral bending of centra, and, finally, lateral curvature of vertebral column.

2384. Kulikov, N.V. and L.N. Ozhegov. 1976. Accumulation of ^{90}Sr-^{90}Y by developing eggs and larvae of whitefish Coregonus lavaretus L. Soviet Jour. Ecology 7:175-177.

Whitefish eggs and larvae were held in a solution of Sr-90 Cl_2, at 0.01 mCi/l. No strontium-90 was accumulated in eggs over 120 days; for yttrium-90 the coefficient of accumulation (CA) on a wet wt basis was 25 at day 40, 55 at day 80, and 80 at day 120. Larval accumulation of Sr-90 increased almost linearly from CA of 0.3 at start to 1.5 on day 32. Y-90 level was always slightly higher, with a CA of 3.5 on day 32. Excretion of radionuclides decreased with time in both eggs and larvae: Sr-90 in eggs dropped to 0.0 in 1 day; Y-90 dropped to 25% on day 4, 10% on day 8 , and 0.0 on day 16. In larvae, Sr-90 content declined to 60% on day 2, 50% on day 8, and 40% on day 16; Y-90 decreased to 60% on day 2, and continued at that level through day 16.

2385. Latz, M.I. and R.B. Forward, Jr. 1977. The effect of salinity upon phototaxis and geotaxis in a larval crustacean. Biol. Bull. 153:163-179.

Larvae of the crab Rhithropanopeus harrisii acclimatized to 20 o/oo S showed a greater positive phototaxis to higher intensities of light and a reduced negative phototaxis to low light intensities when suddenly exposed to 40 o/oo S. Exposure to 5 o/oo S generally reversed phototaxis at light intensities above 0.01/Wm^2. A salinity decrease of 1 to 2 o/oo reversed the phototaxic sign for both stage I and IV zoeae, regardless of acclimation salinity. Total recovery to positive phototaxis occurred in about five minutes. At all test salinities, between 5 and 40 o/oo, stage IV larvae maintained a lower position in the water column than stage I larvae, regardless of light conditions. Stage I zoeae moved downward in salinities below acclimation and upward in higher salinities, responding to phototaxis rather than geotaxis. Stage IV zoeae also migrated downward upon salinity reduction, responding to geotaxis. Ascent in higher salinities occurred only under overhead lights, indicating movement resulting from phototaxis. Authors concluded that these behavioral responses act as a negative feedback system to keep larvae within a region of acclimation salinity in a vertical water column.

2386. Lloyd, E.T., W.T. Schrenk, and J.O. Stoffer. 1977. Mercury accumulation in trout of southern Missouri. Environ. Research 13:62-73.

Concentrations of mercury in rainbow and brown trout ranged from 0.08 to 0.49 mg/kg wet wt in flesh; concentrations in liver were slightly higher. There was no relation between mercury content and fish size. Previous analyses of trout collected in the mid- to late 1940s from the same areas indicated mercury accumulation of approximately 3.0 mg/kg. Over the past 25 years there appears to be a decrease in mercury found in trout of southern Missouri.

2387. Lorz, H.W. and B.P. McPherson. 1977. Effects of copper and zinc on smoltification of coho salmon. U.S. Environ. Protect. Agen. Rept. EPA-600/3-77-032, Corvallis, Oregon: 68 pp.

LC-50 (96 hr) values for Cu as $CuCl_2$ for yearling coho salmon, Oncorhynchus kisutch, ranged from 0.060 to 0.074 mg/l, depending on degree of smoltification. For Zn, the LC-50 (96 hr) value for yearling coho in April was 4.60 mg/l, at 10 to 12°C. Exposure to $\leq$2.00 mg Zn/l for 144 hrs in freshwater had little effect on Na^+, K^+-activated ATPase activity in gill microsomes or on survival of yearling coho when transferred to seawater. However, immersion in 0.005-0.030 mg Cu/l in freshwater for a maximum of 172 days had deleterious effects on downstream migration in natural streams, lowered gill ATPase activity, and reduced subsequent survival in seawater. Exposures

>10 days to Cu had more severe effects than 6 days on migration and survival, but not on gill ATPase. Coho yearlings transferred to non-toxicant freshwater, following exposure to toxicants, showed higher survival upon transferral to seawater than fish transferred immediately. Fish ceased feeding in 0.02 and 0.03 mg Cu/l, and did not resume feeding for several weeks to 4 months; mean lengths and condition factors of these groups were lower than controls. Exposure of yearlings to 0.02 and 0.03 mg Cu/l in freshwater affected normal maintenance of osmotic pressure and Cl concentrations in blood plasma; plasma osmolarity and Cl levels increased significantly compared to controls when transferred to seawater. These responses are attributed in part to suppression of Na^+, K^+-activated ATPase activity in gills.

2388. Lowman, F.G., J.H. Martin, R.Y. Ting, S.S. Barnes, D.J.P. Swift, G.A. Seiglie, R.G. Pirie, R. Davis, R.J. Santiago, R.M. Escalera, A.G. Gordon, G. Telek, H.L. Besselievre, and J.B. McCanless. 1970. Bioenvironmental and radiological-safety feasibility studies, Atlantic-Pacific interoceanic canal. Estuarine and Marine Ecology, Vol. I-IV. Prepared for Battelle Memorial Institute, 505 King Ave., Columbus, OH, Contract AT (26-1)-171.

Hundreds of species of algae, fish and invertebrates collected from Panamanian and Columbian waters during 1967 were analyzed by atomic absorption for Zn, Fe, Mn, Ca, and Sr. Results were presented for each sample on wet, dry and ash weight bases. Maximum values recorded, in mg element per kg ash wt for each taxonomic group sampled during the dry season of 1967 are summarized below (max. scandium value for plankton was 7.7 mg/kg ash wt).

	Zinc	Iron	Manganese	Calcium	Strontium
plankton	2150	67,000	475	274,700	100,000
pelycopod flesh	340	500	12	17	—
pelycopod shell	2050	142	50	506	1750
gastropod flesh	6500	13,000	370	92	510
gastropod shell	330	680	140	500	2194
gastropod viscera	13,000	6100	23	53	84
gastropod operculum	6000	50,000	17,000	85	200
shrimp flesh	1600	920	24	100	510
shrimp carapace	1200	8300	100	720	6000
shrimp whole	790	640	90	480	1500
lobster flesh	600	34	11	18	59

lobster carapace	88	100	21	230	4000
lobster head	140	130	26	280	6800
fish, plankton feeders					
flesh	770	130	—	42	--
viscera	260	75	—	24	--
skin	590	97	36	220	trace
bone	400	180	73	500	trace
whole	400	300	43	76	130
fishmeal	600	1040	125	157	--
fish, pelagic					
white flesh	1200	2700	28	52	200
dark flesh	800	3100	12	14	100
viscera	21,000	3000	22	7000	130
skin	9500	5100	72	460	150
bone	880	5000	45	430	420
fish, bottomfish					
flesh	640	200	16	98	—
viscera	1700	39,000	470	170	300
skin	1000	11,000	69	400	1900
bone	420	1200	170	500	630
whole	1000	10,000	170	320	300

2389. Lowman, F.G., D.K. Phelps, R.Y. Ting, and R.M. Escalera. 1966. Progress Summary Report No. 4, Marine Biology Program June 1965-June 1966. Puerto Rico Nuclear Center Rept. PRNC 85: 57 pp. and Appendices A-F.

The amounts of the trace elements iron, manganese, cobalt, copper, nickel, chromium, zinc, cadmium, strontium, lithium, lead, rubidium, scandium, samarium, and the major elements potassium, calcium, and magnesium have been determined in marine organisms (including algae, plankton, mollusks, coelenterates, crustaceans, fishes, elasmobranchs, sponges, echinoderms), seawater, seston and marine sediments as well as selected rocks, minerals, and soils of the Culebrinas, Anasco and Guanajibo River valleys. The amounts of trace elements in organisms have been related to ash, wet and dry weights, and to organic carbon and nitrogen. Concentration factors of algae, bacteria, crustaceans, and polychaete annelids for Ta-182, Na-24, Zn-65, and Ag-110 are in progress. Stable element analyses have been incorporated into a study of the partitioning of Fe, Sc, Zn, and Sm within a benthic infaunal community. Trace element relationships in various food webs are in progress.

2390. Luoma, S.N. 1976. The uptake and interorgan distribution of mercury in a carnivorous crab. Bull. Environ.

Contamin. Toxicol. 16:719-723.

Portunid crabs, Thalamita crenata, were fed Hg-203 (70 ug/kg fresh wt stable Hg) labelled polychaetes, Neanthes succinea, for 13 days. Feeding rates among the crabs ranged from 0.17 to 1.02 ug Hg-203 ingested/kg crab/day due to variations in body weight. Slopes of the regressions comparing feeding rate with Hg-203 uptake show Hg accumulation into body muscle by 7.5 times. Mercury concentrations in tissues of crabs in ug/kg wet wt ranged from 20 to 58 in chela muscle, 27 to 61 in body muscle, 21 to 44 in viscera, and 33 to 119 in gills. In contrast to laboratory studies, total Hg levels in body muscle of crabs collected from field locations were always higher than visceral levels.

2391. Luoma, S.N. 1977. Physiological characteristics of mercury uptake by two estuarine species. Marine Biology 41:269-273.

Rapid uptake and slow loss of mercury will result from short exposures of some organisms due to transformation of Hg to a slowly exchanging form within the organisms. Differences between exposure times and depuration times depend on rate of transformation during uptake. Concentrations of Hg-203 labeled $HgCl_2$ that exceeded stable Hg levels in seawater, by at least ten times were used i.e. 0.03 to 0.05 ug/l. The largest proportion of Hg accumulated by the worm, Neanthes succinea, 84-92%, was in the slowly-exchanging, ethanol-insoluble physiological compartment of the body, from seawater containing from 0.5 to 5.1 ug Hg-203/l. After 24 hrs in 1.0 ug/l, the concentration in the ethanol-insoluble compartment was 0.28 ug Hg/kg, while the ethanol-soluble section was approximately 0.05. The shrimp, Palaemon debilis, also took up most (65%) of its Hg into the slowly-exchanging compartment. Influx of Hg in the worm, in 1.0 to 1.2 ug Hg/l solute, into the whole animal and slowly-exchanging compartment at 111.0 and 92.0 ug/kg/hr, respectively, was much higher than efflux from both rapidly and slowly-exchanging compartments at 3.6 and 0.4 ug/kg/hr. The influx into whole body of shrimp at 15.7 ug/kg/hr was also higher than efflux from its rapidly and slowly-exchanging compartments at 9.3 and 0.5 ug/kg/hr, respectively. Author concluded that interspecies differences in susceptibility to mercury may be determined by differences in biological transformation rates and physiological permeability.

2392. Luoma, S.N. 1977. The dynamics of biologically available mercury in a small estuary. Estuarine Coastal Marine Sci. 5:643-652.

Concentrations of total mercury in the shrimp Palaemon debilis and the polychaete Nereis succinea from Ala Wai Canal in Hawaii were 15-302 ug/kg, and 8-130 ug/kg wet wt, respectively. In the laboratory, mercuric chloride accumulation by worms fed terrigenous sediment was 1805 ug/kg dry wt after 11 days; for shrimp accumulation was 194 ug/kg dry wt after 14 days. Accumulation of Hg from solution exceeded concentrations in the water by 100-350 times. Salinities as low as 6 o/oo had no effect on Hg uptake by shrimp; however, Hg accumulation in worms decreased at salinities below 16 o/oo. A simulation of mercury levels in shrimp from the estuary, based upon a mathematical model of Hg-203-$HgCl_2$ exchange in this species, showed that mercury concentrations in P. debilis were never at steady state during the field sampling period. Shrimp appeared to rapidly concentrate solute mercury which periodically entered the estuary in storm runoff. Between rainstorms little of the mercury remaining in the estuary (primarily in sediment-bound form) appeared to be available to either the deposit-feeding shrimp or the worm. Because net loss of mercury from both species was slow relative to the rate of uptake, long periods of time were necessary to lose the mercury accumulated during rainstorms.

2393. Luoma, S.N. 1977. Detection of trace contaminant effects in aquatic ecosystems. Jour. Fish. Res. Bd. Canada 34:436-439.

Tolerance to toxicants by various aquatic groups including algae, fish, insects, and annelids is reviewed, noting examples with Cd, Cu, Ni, Pb, and Zn. If one population of a species is more resistant to a toxicant than other populations, it is considered evidence that concentrations of the toxicant in the environment of resistant populations is sufficient to elicit biological effects. Presence of a toxicant-resistant population of one species in an ecosystem further suggests that other species may have been affected by the resistance-eliciting substance.

2394. MacInnes, J.R., F.P. Thurberg, R.A. Greig, and E. Gould. 1977. Long-term cadmium stress in the cunner, Tautogolabrus adspersus. U.S. Dept. Comm. Fish. Bull. 75:199-203.

Mean gill-tissue respiratory rates exhibited by control fish and those exposed to 0.05 and 0.10 mg/l Cd were 972, 736, and 665 ml O_2/hr/kg dry wt, respectively, after 30 days; and 1036, 702, and 587, respectively, after 60 days. At 0.05 mg/l Cd, mortality was 6.9% after 30 days and 11.7% after 60 days. For 0.10 mg/l Cd, these values were 12.1% and 32.3%. Changes were also observed in two liver enzymes: aspartate aminotransferase activity was lowered and glucose-6-phosphate dehydrogenase activity was increased in the presence of 0.05 and 0.10 mg Cd/l. Gill, muscle, and liver tissues from each exposure group were analyzed for Cd uptake; nearly all experimental samples and controls were below analytical detection limits.

2395. Mackenzie, F.T., M. Stoffyn, and R. Wollast. 1978. Aluminum in seawater: control by biological activity. Science 199:680-682.

The distribution and concentration of dissolved aluminum in a vertical hydrographic profile of the Mediterranean Sea near Corsica are controlled by biological activity. The concentrations of dissolved silica and aluminum covary in the profile and exhibit minima coincident with the seasonal thermocline, a nitrate minimum, and an oxygen maximum. These observations support the hypothesis that the silicon and aluminum cycles in the oceans are linked through the activity of diatoms.

2396. MacLeod, M.G. 1977. Effects of salinity on food intake, absorption, and conversion in the rainbow trout, Salmo gairdneri. Marine Biology 43:93-102.

In trout acclimatized to experimental salinities, weekly food intake was a maximum of 26% dry wt at 15.0 and 28.0 o/oo S; 23 and 24% at 0.0 and 7.5 o/oo S respectively; and a low of 17% at 32.5 o/oo S. Daily food intake in freshwater varied from 0 to 42 g over 40 days. When salinity was abruptly increased, growth rates decreased in relation to food intake decrease. Weekly growth rate decreased from >7% to -3% as salinity increased from 0.0 to 7.5 to 15.0 to 28.0 o/oo. Over the same salinities, weekly food intake decreased from 35 to 15% dry wt. Recovery of food intake and growth rates to pre-change levels occurred within 14 days. Absorption efficiency was negatively related to salinity. Total dry matter decreased in efficiency from 0.89 to 0.80 as salinity increased from freshwater to 32.5 o/oo S. Total energy decreased from 0.92 to 0.83 and total nitrogen decreased from 0.96 to 0.90 over the same increase. Conversion efficiency declined with salinity increase. Dry matter in trout 50 to 95 g in weight decreased in efficiency from about 0.25 to about 0.16 as salinity increased from 0.0 to 32.5 o/oo S. Energy decreased from 0.27 to 0.17, as total nitrogen declined from 0.35 to 0.21. In trout weighing 80 to 155 g, conversion efficiencies of all three parameters increased slightly until salinity reached 28.0 to 32.5 o/oo S, when efficiency dropped sharply.

2397. MacLeod, M.G. 1977. Effects of salinity on fasted rainbow trout, Salmo gairdneri. Marine Biology 43:103-108.

Trout which had been maintained for 120 days in freshwater and salinities of 7.5, 15.0 and 32.5 o/oo at 10 C were starved for up to 48 days under these same environmental conditions. Live weight loss between days 7 and 48 of starvation could be described by a straight line, as could the decrease in condition factor. Trout maintained in 32.5 o/oo S showed a significantly greater weight loss than those in lesser salinities. Muscle water content fell from 78.0 to 74.0% between days 19 and 32 in 32.5 o/oo S; water content increased slightly from 77.5 to 78.5% in other salinities. Liver water content and volume of gall bladder contents changed slightly.

2398. Marchyulenene, D.P. and G.G. Polikarpov. 1976. Role of water and food in the entry of certain radionuclides into the organism of the pond snail. Soviet Jour. Ecology 7:170-172.

Accumulation of strontium-90, cesium-137, cerium-144, and ruthenium-106 from the medium by snails, Limnaea stagnalis, and plants, Elodea canadensis, was observed. Snails nourished by labelled Elodea for an unrestricted time accumulated 1.4X more radionuclides in body and shell than molluscs fed only 3-4 hrs each day; with Sr-90, shell accumulated 3.4X more with unrestricted feeding. Maximum coefficient of accumulation (CA) on a dry wt basis was 10,500 for Ce-144 in body over labelled water. CA values for radionuclides in snails maintained in labelled water were significantly higher than in nonlabelled water regardless of diet. Molluscs accumulated more Sr-90 in body by 27X and in shell by 50X, and more Ce-144 in body by 2X and in shell by 20X from labelled water than from labelled Elodea. When radionuclide concentration in snails from labelled water with labelled Elodea was computed as 100%, molluscs accumulated Sr-90 and Ce-144 from labelled food in shells only at

2 and 5%, respectively, and in body at 4 and 26%. Higher levels of accumulation of Ce-144 and Ru-106 in mollusc body with labelled Elodea were apparently connected with high CA of these radionuclides in the food material, 1040 and 216, respectively.

2399. Martin, M., M.D. Stephenson, and J.H. Martin. 1977. Copper toxicity experiments in relation to abalone deaths observed in a power plant's cooling waters. Calif. Fish Game 63:95-100.

Toxicity of copper as $CuSO_4$ to adult and larval red abalone, Haliotis rufescens, and adult black abalone, Haliotis cracherodii, was determined by static bioassay in seawater at 14 C. The LC-50 (96 hr) values were 50 ug Cu/l for adult black abalone, and 65 ug/l for adult red abalone. The LC-50 (48 hr) value for red abalone larvae was 114 ug Cu/l. Copper accumulated in gills of red and black abalone from ambient seawater concentrations of 56 ug Cu/l. Histopathological abnormalities in gill tissues was observed at seawater concentrations of 32 ug Cu/l and higher.

2400. Matsunaga, K. 1976. Estimation of variation of mercury concentration in the oceans during the last several decades. Jour. Oceanograph. Soc. Japan 32:48-50.

Mercury in the northern North Pacific Ocean and Bering Sea from the surface to a depth of 1600 m ranged from 0.003 to 0.004 mg/l in summer 1965. As body length of rock fish, Sebastes iracunda, recently caught from this area, rose from 25 to 45 mm, Hg body concentrations rose linearly from 0.10 to 0.55 mg/kg dry wt. This same relationship was observed in fish caught in 1962, 1953 and 1951. It was concluded that there was little variation of mercury concentration in these oceans during the last several decades.

2401. Mayes, R.A., A.W. McIntosh, and V.L. Anderson. 1977. Uptake of cadmium and lead by a rooted aquatic macrophyte (Elodea canadensis). Ecology 58:1176-1180.

Elodea were grown in two lakes with different sediment concentrations of Pb and Cd. Wildlife Area Lake sediments contained 0.5 to 3.8 mg Cd/kg dry wt and 16.6 to 23.7 mg Pb/kg dry wt. Little Center Lake sediments contained 88.4 to 125.3 mg Cd/kg and 392.5 to 487.8 mg Pb/kg. Little Center Lake receives waste water from a nearby electroplating plant. Specimens in each lake were anchored in either control or contaminated (Cd and Pb) sediments. Water samples from Wildlife Area were below detection limits of 0.0002 mg Cd/l and 0.005 mg Pb/l. Little Center waters averaged 0.002 to 0.006 mg/l Cd in summer, and 0.009 to 0.027 mg Pb/l. Plants grown in the same water but in sediment from different sources had significantly different concentrations of Pb and Cd. _Elodea_, with initial Cd at 0.3 mg/kg dry wt, grown in WA Lake decreased from 2.0 to 0.3 mg/kg when anchored in WA sediment, and from 7.5 to 4.0 in LC sediment over 9 weeks. In LC Lake, Cd levels in _Elodea_ peaked at 12.2-26.8 mg/kg in WA sediment at 6 weeks before decreasing, while peaking at 23.6-32.3 in LC sediment. Initial Pb concentration in _Elodea_ was 2.9 mg/kg. This level decreased from 10.4 to 5.2 mg Pb/kg in WA Lake with WA sediment, and from 64.1 to 18.4 in LC sediment. In LC Lake, Pb levels peaked at 32.7-85.9 mg/kg in WA sediment at 6 weeks before decreasing, while peaking at 114.2-160.9 in LC sediment.

2402. McCarty, L.S., J.A.C. Henry, and A.H. Houston. 1978. Toxicity of cadmium to goldfish, _Carassius auratus_, in hard and soft water. Jour. Fish. Res. Bd. Canada 35:35-42.

Goldfish were exposed to up to 60 mg Cd/l in relatively soft, (≈20 mg/l as $CaCO_3$), and hard (≈140 mg $CaCO_3$/l) waters. In soft water, the LC-50 (48 hr) value was 2.76 mg Cd/l; the LC-50 (96 hr) was 2.13; and the LC-50 (240 hr) 1.78 mg/l. During trials in hard water, there were transient increases in particulate Cd and sharp decreases in total Cd. Total alkalinity, pH, and conductivity exhibited Cd-dependent variations. LC-50 (48 hr) was 46.9 mg Cd/l and LC-50 (96 hr) was 26.8 mg/l. The LC-50 (240 hr) value of 40.2 mg Cd/l was considered less precise due to water quality variations.

2403. McKim, J.M. 1977. Evaluation of tests with early life stages of fish for predicting long-term toxicity. Jour. Fish. Res. Bd. Canada 34:1148-1154.

Partial and complete life-cycle toxicity tests with fish, involving all developmental stages, have been used extensively in the establishment of water-quality criteria for aquatic life. During extended chronic exposures of fish to selected toxicants, certain developmental stages have frequently shown a greater sensitivity than others. In 56 referenced life-cycle toxicity tests completed during the last decade with 34 organic and inorganic chemicals (including Cd, Cu, Cr, Pb, Ni, Zn, methylmercury) and four species of freshwater teleosts, the embryo-larval and early juvenile life stages were the most, or among the most, sensitive. Tests with these stages can be used to estimate the maximum acceptable toxicant concentration (MATC) within a factor of two in most cases. Therefore, toxicity tests with early life stages of fish should be useful in establishing water-quality criteria and in screening large numbers of chemicals. MATC values for Cd ranged from 1.7 to 80.0 ug/l; for Cu these were 9.5-40.0 ug/l; for Cr 200.0 to 3950.0 ug/l; for Pb 31.3-119.0 ug/l; Ni 380.0-730.0 ug/l; Zn 26.0-1368.0 ug/l; mixtures of Zn, Cd, and Cu 3.9-42.3 ug/l; and for CH_3Hg^+ 0.07-0.93 ug/l.

2404. McLean, R.O. and A.K. Jones. 1975. Studies of tolerance to heavy metals in the flora of the rivers Ystwyth and Clarach, Wales. Freshwater Biol. 5:431-444.

The river Ystwyth is contaminated by heavy metals, especially below the areas of old lead mines. *Hormidium rivulare* was the most tolerant filamentous green algae present. *Scapania undulata* was a tolerant bryophyte on the Ystwyth and Clarach rivers and was found alone in polluted sites, but was less frequent in cleaner areas. Metal extracts from *Scapania* mirrored variations in environmental metal concentrations and it was suggested that *Scapina* would be useful as an indicator of water quality. In general, lower levels of Fe, Pb, and Mn were found in *Scapania* compared with the less tolerant bryophyte, *Fontinalis squamosa*. When *Fontinalis* was transplanted to polluted sites, an increase in Pb, Cu, Zn and Mn content was measured within 6 wks, with death to decay after 18 wks. *Scapania* survived when it was transplanted from its natural polluted habitat to a less polluted area, with no marked change in metal composition. Elemental concentrations of Fe, Zn, Cu, Cd, Pb, and Mn in transplanted and non-transplanted samples of *Fontinalis* and *Scapania* are presented. Radiozinc studies under controlled conditions demonstrated that both species of bryophytes had similar zinc uptake patterns, with uptake slightly higher in *Fontinalis*.

2405. McNurney, J.M., R.W. Larimore, and M.J. Wetzel. 1977. Distribution of lead in the sediments and fauna of a small midwestern stream. *In*: Drucker, H. and R.E. Wildung (eds.). Biological implications of metals in the environment. ERDA Symp. Ser. 42:167-177. Avail. as CONF-750929 from Nat. Tech. Inf. Serv., U.S. Dept. Comm., Springfield, VA 22161.

Lead distribution in sediments and fauna in Saline Ditch, Illinois, over a two-year period was highly variable. Differences in sediment Pb levels between stations were associated with amount of urban runoff, whereas differences between samples at a station were attributed to sediment composition. Mean Pb concentration in totally urban drainage areas was nearly 400 mg/kg dry wt; samples from rural areas averaged 13.6 mg/kg. Maximum sediment Pb levels were associated with reduced particle size and increased organic content. Lead levels in sediments, ranging from 10 to 400 mg/kg dry wt, were generally 6 orders of magnitude higher than water concentrations. Lead burdens in many aquatic organisms were affected by substrate contact, as well as stream location. Pb accumulations in benthic organisms, including mayflies Hexagenia limbata, tubificid and nontubificid oligochaete worms, crayfish Orconectes virilis, and pelecypod ranged from 5.3 to 16.0 mg/kg dry wt. Fishes Etheostoma nigrum, Catostomus commersoni, Pimephales notatus, Semotilus atromaculatus, Ericymba buccata, and Notropis umbratilus contained 1.4 to 4.1 mg Pb/kg dry wt. Oligochaetes, which burrow in and ingest sediment, had highest Pb levels.

2406. Mearns, A.J., P.S. Oshida, M.J. Sherwood, D.R. Young, and D.J. Reish. 1976. Chromium effects on coastal organisms. Jour. Water Poll. Contr. Feder. 48:1929-1939.

Juvenile and adult polychaetes, Neanthes arenaceodentata, exposed to mean concentrations of 1.15 to 1.89 mg/l hexavalent chromium for 7 days, showed LC-50 (4 day) values of 2.22 to 3.63 mg/l. Juveniles exposed to trivalent chromium had LC-50 (4 day) values of 12.5 mg/l. Fifty percent mortality in adult polychaetes was observed on day 184 in 0.1 mg Cr^{6+}/l and on day 59 in 0.2 mg Cr^{6+}/l. Chronic effects of Cr^{6+} showed a reduction of growth and reproductive efficiency in two generations of worms at the lowest concentration tested of 0.0125 mg/l. No significant differences in test parameters were evident between controls and worms exposed to trivalent chromium. A summary of environmental levels of chromium and effects of Cr^{6+} and Cr^{3+} to marine organisms is presented.

2407. Mearns, A.J. and M.J. Sherwood. 1977. Distribution of neoplasms and other diseases in marine fishes relative to the discharge of waste water. In: Kraybill, H.F., C.J. Dawe, J.C. Harshbarger, and R.G. Tardiff (eds.). Aquatic pollutants and biologic effects with emphasis on neoplasia. Annals N.Y. Acad. Sci. 298:210-224.

Concentrations of trace metals, in mg/kg dry wt, in digestive glands of mussel Mytilus californianus from southern California coastal waters were 14-69 for copper and 2.7-61.0 for chromium, as reported earlier. Copper in liver of Dover sole, Microstomus pacificus, from the same areas had been reported as 1.1-32.6 mg/kg wet wt. In an 8-year study (1969 to 1976), fin erosion in M. pacificus was the only disease that appeared to be directly associated with municipal waste discharges into southern coastal California. It occurred primarily at Palos Verdes shelf, apparently resulting from exposure to contaminated sediments. Tumor diseases discussed in this report did not appear to be related to municipal waste water discharge sites or discrete sources of pollutants.

2408. Mears, H.C. and R. Eisler. 1977. Trace metals in liver from bluefish tautog and tilefish in relation to body length. Chesapeake Science 18:315-318.

Livers from bluefish Pomatomus saltatrix, tilefish Lopholatilus chamaeleonticeps, and tautog Tautoga onitis collected during the summer of 1971 off the New Jersey coast were analyzed for Cd, Cr, Cu, Fe, Mn, Ni, and Zn by atomic absorption spectrophotometry. For all samples the following extreme values, in mg element/kg liver ash, were recorded: tautog Cd all < 7, Cr 20-450, Cu 280-3700, Fe 2500-31,000, Mn 20-300, Ni 30-470, Zn 700-2300; bluefish Cd 10-150, Cr 30-390, Cu 150-1600, Fe 3900-60,000, Mn 100-240, Ni 20-330, Zn 1100-7600; tilefish Cd 20-270, Cr 10-40, Cu 80-590, Fe 13,000-38,000, Mn 60-150, Ni 10-40, and Zn 1100-2800. Liver ash from male and female tautog contained decreasing concentrations of Ni with increasing body length. Smaller males also contained greater levels of Cr and Cu in liver than larger male tautogs. Larger tilefish contained proportionately more Cd, Cu, and Fe in liver than smaller tilefish. Decreasing levels of Mn and Zn with body length were apparent only for female tilefish. Livers from larger male bluefish were associated with higher concentrations of Fe than those from smaller males, while those from larger females contained lower concentrations of Cr than did livers of smaller females. Authors concluded that body length should be a factor in interpretation of trace metal residues in marine teleosts.

2409. Meisch, H.-U., H. Benzschawel and H.-J. Bielig. 1977. The role of vanadium in green plants II. vanadium in green algae - two sites of action. Arch. Microbiol. 144:67-70.

Cells of Chlorella pyrenoidosa, derived from vanadium-free agar slants, were sensitive to microamounts of V as NH_4VO_3. Between 0.01 and 1.0 ug V/l, algae responded with a continuous increase in dry weight. Addition of 0.1 and 1.0 ug V/l increased dry weight 43% and 67%, respectively, after 7 days. At higher V concentrations, increased biomass was accompanied by an increase in chlorophyll content. The maximum effect on both parameters occurred at 500 ug V/l with a 100% increase in weight in 7 days. However, both weight and chlorophyll content decreased at 25 mg V/l and higher, with death evident at 100 mg V/l. Vanadium residues above 150-200 mg/kg dry wt in Chlorella were toxic. Two different pH optima for V action were observed. The first at pH 7 was associated with an increase of 100% in dry weight over 7 days. The second at pH 7.5-8 accounted for a 90% increase in chlorophyll content over 7 days, and suggests the existence of two V-dependent metabolic events in green algae.

2410. Menasveta, P. and R. Siriyong. 1977. Mercury content of several predacious fish in the Andaman Sea. Marine Poll. Bull. 8:200-204.

Total mercury concentrations in fish muscle collected from the Andaman Sea off Thailand in April 1975 ranged from 0.026 to 0.234 mg Hg/kg wet wt in yellowfin tuna Neothunnus albacora, from 0.027 to 0.233 in bigeye tuna Parathunnus sibi, and from 0.057 to 0.478 in the sharks Isurus guntheii, Bulamia ftallamzami, Sphyrna tades, and Alopius sp. A positive linear correlation existed between Hg concentration and weight for all species. Rates of total Hg accumulation between yellowfin and bigeye tuna were not significantly different. Comparison between Hg levels in Andaman yellowfin and higher values in Central Pacific yellowfin is discussed.

2411. Merlini, M. and G. Pozzi. 1977. Lead and freshwater fishes: part 2 - ionic lead accumulation. Environ. Poll. 13:119-126.

When 0.5 mg Pb/l was added to Lake Maggiore water in North Italy as lead nitrate, only 8% remained in ionic state. Immature goldfish, Carassius auratus, in lake water with Pb-203 and 0.5 mg Pb/1, accumulated lead rapidly to a concentration factor (CF) of 390 by day 10 and leveled off to 425 by day 25. In Pb-203 and 0.5 mg Pb/1 after 10 day pretreatment with 0.5 mg Pb/1, goldfish took up lead slightly faster, with CF of 409 on day 10 and 492 on day 27. CF values were 772 and 896 on days 10 and 27, respectively, when goldfish were exposed only to Pb-203 in lake water. After 27 day exposure to the three conditions of lead, total body burden of Pb-203 in fish held 7 days in non-labelled water had declined from 43.5 to 30.2% with Pb-203 and stable Pb, 46.1 to 22.6% with pretreatment, and 36.4 to 14.8% with only Pb-203. Authors conclude that fish accumulate lead in ionic form, and that Pb-203 was rapidly taken up and lost in two exponential phases.

2412. Middaugh, D.P., W.R. Davis and R.L. Yoakum. 1975. The response of larval fish, *Leiostomus xanthurus*, to environmental stress following sublethal cadmium exposure. Contrib. Marine Sci. 19:13-19.

An incipient LC-50 concentration of approximately 0.2-0.3 mg Cd/1 was calculated following exposure for 200 hours. The LC-50 (30 hr) was 6 mg Cd/1, for 172 hrs the LC-50 was 0.3 mg/1. No larvae died after 200 hr exposure to 0.1 mg/1. Whole body burdens of survivors in mg Cd/kg ash, after 96 hr exposure to 0.09, 0.5, and 0.8 mg Cd/1 were 20, 42 and 137, respectively. Larval spot exposed to the four highest concentrations of cadmium, 0.8-8.0 mg/1, died rapidly with no indication of irritability prior to death. Larvae subjected to concentrations of 0.3 and 0.6 mg/1 exhibited a phase of disoriented swimming at the surface of treatment aquaria for 5-7 hrs before dying. Subsequent short-term sublethal tests were conducted to determine the relationship of cadmium exposure and accumulated whole body residues on response of larvae to thermal stress and to low dissolved oxygen. Results indicated a significant decrease in the critical thermal maximum for larvae exposed to 0.5 and 0.8 mg/1 cadmium for 96 hrs at 20 C. Significant decreases in survival of larvae subjected to a dissolved oxygen level of 1.6 mg/1 after exposure to 0.5 and 0.8 mg/1 cadmium were also observed.

2413. Middaugh, D.P., and J.M. Dean. 1977. Comparative sensitivity of eggs, larvae and adults of the estuarine teleosts, *Fundulus heteroclitus* and *Menidia menidia* to cadmium. Bull. Environ. Contamin. Toxicol. 17:645-652.

Mortality or non-emergence of larvae from eggs of Fundulus in 0.32 mg cadmium/l was 20% in 20 o/oo salinity and 23% in 30 o/oo salinity. Cd at 1.0 mg/l killed 27 (20 o/oo) and 47% (30 o/oo); 3.2 mg Cd/l killed 30 and 50%; 10.0 mg Cd/l killed 40 and 54%, and in 32.0 mg Cd/l 54 and 54% were dead, respectively. Death in controls was 17% and 33%. For Menidia, mortality in 0.32 mg Cd/l was 50% in 20 o/oo S and 38% in 30 o/oo S; 1.0 mg/l killed 36 and 36%, 3.2 mg/l killed 58 and 40%, 10.0 mg/l killed 52 and 38%, and 32.0 mg/l killed 66 and 50%, respectively. In controls, mortality was 36% (20 o/oo S) and 33% (30 o/oo S). In 20 o/oo, LC-50 (48 hr) values, in mg Cd/l, for Fundulus larvae were 16.2 at age 1 day, 9.0 at 7 days, and 32.0 at 14 days. In 30 o/oo, values for larvae were 23.0, 12.0, and 7.8 at the respective ages. Menidia larvae, in 20 o/oo, had LC-50 48 hr values, in mg Cd/l, of 3.8 at age 1 day, 3.2 at 7 days, and 2.2 at 14 days. In 30 o/oo, values for larvae were 5.6, 3.4, and 1.6 at the respective ages. The LC-50 48 hr values, in mg Cd/l, for adult Fundulus were 60.0 in 20 o/oo, and 43.0 in 30 o/oo. For adult Menidia, values were 13.0 mg Cd/l in 20^{o}/oo and 12.0 in 30 o/oo.
From results, authors emphasize use of different developmental stages of test species when establishing water quality criteria.

2414. Miller, W.E., J.C. Greene, and T. Shiroyama. 1975. Applications of algal assays to define the effects of wastewater effluents upon algal growth in multiple use river systems. In: Biostimulation and nutrient assessment (PRWG 168-1) workshop proceedings. Water Research Lab, Utah State Univ., Logan, Utah: 77-92.

Zinc concentrations in the Spokane River system in Washington and Idaho ranged from < 0.02 mg/l to 7.5 mg/l. Biomass of the algae Selenastrum capricornutum was 0.02-0.03 mg dry wt/l after 14 days immersion in 0.04 or 0.10 mg Zn/l. Addition of 1.0 mg EDTA/l to zinc water supported growth comparable to controls, indicating metal toxicity was suppressed. Growth in metal-free was higher water at 10 mg dry wt/l. Algal growth was also correlated positively with N and P content of natural waters.

2415. Mills, A.L. and R.R. Colwell. 1977. Microbiological effects of metal ions in Chesapeake Bay water and sediment. Bull. Environ. Contamin. Toxicol. 18:99-103.

Effect of chromium, cadmium, cobalt, lead, and mercury salts on C-14 O_2 uptake by marine algae and microorganisms from Chesapeake Bay was determined. The alga Dunaliella was not affected by 25 or 100 mg/l of Cr, Cd, or Co. Uptake in 25 mg Pb/l was reduced to 75% of control values; in 100 mg Pb/l this was reduced to 50%. Hg at 2.5 and 10 mg/l decreased uptake to 25 and 22%, respectively. Chlorella showed no effect to 25 or 100 mg/l of Cr, Co, or Pb, or 100 mg/l of Cd. Uptake was reduced to 87% in 25 mg Cd/l, to 34% in 2.5 mg Hg/l, and to 0% in 10 mg Hg/l. Microogranisms in Bay water were not affected by levels tested of Cr or Pb. However, uptake was reduced to 67 and 48% in 25 and 100 mg Cd/l, respectively, to 93 and 60% in 25 and 10 mg Co/l, and to 8 and 4% in 2.5 and 10 mg Hg/l. Inhibition of C-14 glucose oxidation to microorganisms in water and sediment samples from two sites in the Bay was 47-100% and 73-100% in 10 and 100 mg Co/l, respectively, 0-35% and 0-94% in 10 and 100 mg Cr/l, 19-73% and 30-81% in 10 and 100 mg Pb/l, and 0-84% and 51-94% in 10 and 100 mg Cd/l. In 10 mg Hg/l, C-14 glucose oxidation was reduced up to 97% for water, 0% for sediment; for 100 mg Hg/l a similar pattern was recorded. Heterotrophic microorganisms from Colgate Creek, a recipient of high anthropogenic metal input, were more metal-resistant than those from relatively clean Chesapeake Beach.

2416. Mills, B.J., P. Suter, and P.S. Lake. 1976. The amount and distribution of calcium in the exoskeleton of intermoult crayfish of the genera Engaeus and Geocharax. Austral. Jour. Marine Freshwater Res. 27:517-523.

Total exoskeleton calcium concentration is low in crayfish Engaus fossor, E. leptorhynchus, Engaeus sp., and Geocharax falcata in comparison with most other crustaceans, especially decapods. Concentrations ranged from 45,600 to 74,700 mg Ca/kg wet wt with mean percentage concentrations of 5.21-6.15%. Results suggest that total exoskeleton Ca decreases with increasing size in Engaeus sp. and E. fossor, while G. falcata maintains a constant Ca level with increasing size. Reduction in relative calcification may be an adaptation to low Ca concentrations in water inhabited by crayfish. Distribution of Ca in exoskeletons of the four species were 133,000-245,000 mg Ca/kg wet wt in cheliped, 88,000-200,000 in antenna, 82,000-195,000 in carapace, 63,000-119,000 (also a high of 880,000) in legs, 82,000-150,000 in abdomen, 108,000-164,000 in telson, and 71,000-141,000 in uropod. Ca distribution was dissimilar between crayfish species; significance of these differences is discussed in relation to habitat requirements of each species.

2417. Mitchell, B.D. and M.C. Geddes. 1977. Distribution of the brine shrimps *Parartemia zietziana* Sayce and *Artemia salina* (L.) along a salinity and oxygen gradient in a south Australian saltfield. Freshwater Biol. 7:461-467.

The seasonal distribution of *P. zietziana* and *A. salina* was studied in a south Australian saltfield. *P. zietziana* occurred alone at salinities from 112 to 214 o/oo and *A. salina* occurred alone at salinities above 285 o/oo; the two species overlapped in the range 214 to 285 o/oo. Respiration experiments indicated that *A. salina* had a lower 'critical' oxygen concentration than *P. zietziana*, apparently due to the presence of hemoglobin in *A. salina*. This may result in an adaptive advantage at high salinity and low dissolved oxygen.

2418. Mukherjee, S. and S. Bhattacharya. 1977. Variations in the hepatopancreatic α-amylase activity in fishes exposed to some industrial pollutants. Water Research 11:71-74.

Effects of phenol, sulphide, copper and ammonia on α-amylase activity was determined in the freshwater teleosts *Ophicephalus punctatus* and *Clarias batrachus*. Three dosage levels of Cu were tested: a low dose in which 80-100% of the test fishes survived (28.0-51.5 mg/l); an LC-50 (48 hr) level (41.5-70.0 mg/l); and a high dose where survival was only 20% (54.0-90.0 mg/l). At low Cu concentrations enzymatic inhibition reached 40% in *O. punctatus* and 21% in *C. batrachus*. Enzyme inhibition was greater in the crude effluent of the four pollutants for 48 hr than in the individual pollutants. This may be due to the high ammonia or to a synergistic action of the toxicants present in the effluent. A 90 day chronic exposure to the undiluted effluent caused no mortality but produced 74% enzyme inhibition in *O. punctatus*.

2419. Munda, I.M. 1977. Combined effects of temperature and salinity on growth rates of germlings of three *Fucus* species from Iceland, Helgoland, and the North Adriatic Sea. Helgol. wiss. Meeresunters 29:302-310.

Growth rate of germlings of *Fucus distichus edentatus* from Iceland, *F. vesiculosus* from Helgoland, North Sea, and *F. virsoides* from the North Adriatic Sea was investigated for 6 months in temperatures from 3 to 15 C and salinites from 2.7 to

31.1 o/oo. Maximum growth rate for F. distichus was at 9 C; growth rate generally increased with temperature for the other two species. Growth increased with increasing salinity for all 3 species of algae. Reduction of growth upon dilution was most pronounced in F. vesiculosus, though in view of its overall distribution, a higher salinity tolerance was expected. Susceptible strains may have developed at Helgoland, where salinity rarely drops below 30 o/oo.

2420. Munda, I.M. and B.P. Kremer. 1977. Chemical composition and physiological properties of fucoids under conditions of reduced salinity. Marine Biology 42:9-15.

Thallus segments of two seaweeds, Fucus serratus and F. vesiculosus, were grown in seawater media at salinities between 32.7 and 2.3 o/oo for a least 2 weeks. Compared to controls, both species exhibited a reduction in dry weight, ash weight, chloride, and mannitol content with decreasing salinity. Total N, in terms of protein contents, increased. Respiratory O_2-consumption was markedly increased at lower salinities, whereas rate of photosynthetic O_2-evolution showed some depression. Salinity had relatively little effect on distribution of photosynthetically assimilated C-14 among the phosphate esters, amino acids, organic acids, and mannitol. Release of C-14 assimilates into the medium never exceeded 2% of total C-14 uptake, but was stimulated in media of reduced salt content. Results are discussed with emphasis on long-term adaptation and osmoregulation.

2421. Nakamura, R., Y. Suzuki, and T. Ueda. 1977. Distribution of radionuclides among green alga, marine sediments and seawater. Jour. Radiation Res. 18:322-330.

Distributions of Co-60, Zr-95-Nb-95, Ru-106-Rh-106, and Cs-137, each added at 0.02 mCi, were examined for 14 days in green alga Ulva pertusa, seawater, and marine sediments from the coast of Japan. Major portions of Co-60, Zr-95-Nb-95, and Ru-106-Rh-106 were in sediments, at 87, 54, and 63%, respectively; 82% of Cs-137 was found in seawater. Ulva contained 41% of the available Zr-95-Nb-95, 26% of Ru-106-Rh-106, 4% of Co-60, and 0.8% of Cs-137. Activity ratios of marine sediments (radioactivity in sediments vs. seawater) were 4000 for Co-60, 30 for Cs-137, 900 for Ru-106-Rh-106, and 1800 for Zr-95-Nb-95.

2422. Namminga, H. and J. Wilhm. 1977. Heavy metals in water, sediments, and chironomids. Jour. Water Poll. Contr. Feder. 49: 1725-1731.

Concentrations in water of Cu, Cr, and Zn at 5 stations along Skeleton Creek, Oklahoma, ranged from 0.003-0.014 mg copper/l in winter to 0.0003-0.004 in summer; from below detection to 0.003 mg chromium/l in winter and from below detection to 0.001 in summer; and from 0.007-0.028 mg zinc/l in winter to below detection-0.004 in summer. Concentrations were dramatically higher at stations near industrial and domestic outfalls. Metal concentrations in sediments along Skeleton Creek were 0.4-1.9 mg/kg in winter and 1.3-6.4 mg/kg in summer for Cu; 1.3-6.3 and 2.4-14.7, respectively, for Cr; 1.0-6.2 and 1.0-10.1 for Pb; and 2.2-9.2 and 2.3-26.6 for Zn. Maximum concentrations were found below waste outfalls. Concentration factors of Cu, Pb, and Zn but not Cr in larval chironomid insects exceeded factors for sediments.

2423. Nelson, D.A., A. Calabrese and J.R. MacInnes. 1977. Mercury stress on juvenile bay scallops, Argopecten irradians, under various salinity-temperature regimes. Marine Biology 43:293-297.

Scallop survival was significantly affected by mercuric chloride and by salinity, as well as by interaction between temperature-Hg concentration, and temperature-salinity. Mercury, then salinity, were the two most important variables affecting survival. Maximal survival at 52 ug Hg/l was estimated to occur between 15.0 and 24.5 C, and salinities between 17.4 and 24.4 o/oo. Biocidal properties of mercury at ≤89 u/l was higher at 25 C and 15 o/oo than at 15 C; this enhancing effect diminished at higher mercury concentrations. The lowest LC-50 (96 hr) value recorded of 57.6 ug Hg/l occurred at the highest temperature, 25 C, and lowest salinity, 15 o/oo, tested. The highest LC-50 (96 hr) value of 134.0 ug/l was observed at 25 C and 22.6 o/oo.

2424. Nestler, J. 1977. Interstitial salinity as a cause of ecophenic variation in Spartina alterniflora. Estuarine Coastal Marine Sci. 5:707-714.

Height of Spartina alterniflora plants on salt marshes in Georgia was related to total dissolved salt concentration of the underlying substrate. Horizontal stability of interstitial water allows formation of interstitial salinity clines on the salt marsh. Pore water salinities are lowest near sources of estuarine or freshwater (20 o/oo) and highest in areas removed elevationally from low saline water sources (up to 40 o/oo). Growth of S. alterniflora is inversely related to interstitial salinity along these clines; growth is robust in lower salinities and weak in higher saline areas. Causal relationship between interstitial salinity and plant growth forms is presented.

2425. Newman, M.W. and S.A. MacLean. 1974. Physiological response of the cunner, Tautogolabrus adspersus, to cadmium. VI. histopathology. In: U.S. Dept. Commerce NOAA Tech. Rept. NMFS SSRF-681:27-33.

Histopathological effects of acute exposure of a marine fish to water containing cadmium chloride were evident in kidney, intestine, hemopoietic tissue, epidermis and gill. Few significant changes were noted in cunners exposed to less than 48 mg Cd/l for 96 hrs. The results implicate renal failure as the probable cause of death after acute exposure to Cd. At 24 mg Cd/l, there was some swelling of intestinal epithelium; at 48 mg/l, columnar cells were swollen, nuclei hypertrophied and nucleoli prominent. At 48 mg Cd/l, kidneys from 3 of 6 fish exhibited diffuse tubular necrosis, and one of these exhibited focal tubular necrosis. Blood spaces in kidneys of fish exposed to 24 and 48 mg Cd/l contained large numbers of cells thought to be immature thrombocytes. Gills of cadmium-exposed fish showed epithelial hypertrophy, hyperplasia of interlamellar epithelium, and desquamation. At 48 mg/l, the epidermis showed swelling of epithelial cells and a paucity of mucus secretion. Percent leucocytes in normal cunner blood (and after 96 hr exposure to 48 mg Cd/l) were: 69.3 (35.9) in mature thrombocytes; 15.6 (50.2) in neutrophils; 11.2 (4.5) in small lymphocytes; 2.2 (1.5) in medium lymphocytes; 0.7 (1.4) in eosinophils; and 1.1 (6.1) in blasts.

2426. Nielsen, S.A. 1975. Cadmium in New Zealand dredge oysters: geographic distribution. Inter. Jour. Environ. Anal. Chemistry 4:1-7.

Mean cadmium levels of 1.4 to 7.9 mg/kg wet wt or 8.7 to 49.6 mg/kg dry wt were found in dredge oysters, Ostrea lutaria, from 24 stations around Foveaux Strait, New Zealand. The Cd content was proportional to body weight up to a body average of about 8-10 g; in larger oysters the Cd content was independent of body wt. These data, in consideration with prevailing winds, indicate that the source of Cd must be west of Foveaux Strait, possibly in Fiordland. High Cd levels in these oysters are naturally occurring since there is no industrial pollution in the area. Compared with Cd concentrations in other oyster species, *O. lutaria* may have a predilection for accumulating Cd.

2427. Nimmo, D.R., D.V. Lightner, and L.H. Bahner. 1977. Effects of cadmium on the shrimps, *Penaeus duorarum*, *Palaemonetes pugio* and *Palaemonetes vulgaris*. *In:* Vernberg, F.J., A. Calabrese, F.P. Thurberg, and W.B. Vernberg (eds.). Physiological responses of marine biota to pollutants. Academic Press, N.Y.:131-183.

P. vulgaris were acutely and chronically more sensitive to Cd as cadmium chloride than *P. duorarum*. No significant differences were shown with Cd as acetate, sulfate, or nitrate. Bioaccumulation of Cd from water occurred at concentrations as low as 0.002 mg/l in *P. duorarum* and 0.008 in *P. vulgaris*. Cd in tissues of *P. duorarum* did not plateau at concentrations <0.003 mg/l, but did plateau in *P. pugio* at >0.005 mg/l within 7 days. Cd in *P. duorarum* varied with water concentrations up to 1.0 mg/l with highest uptake in hepatopancreas, followed by gills, exoskeleton, muscle, and serum in that order. Levels of Cd increased in muscle after Cd-exposed shrimp were transferred to Cd-free water. Natural Cd levels in shrimp were reduced by holding feral animals in flowing water. *P. duorarum*, exposed to Cd near the LC-50 (96 hr) concentration of 3.5 mg/l, consistently developed blackened foci or blackened lamellae in branchia. Occasionally, blackened cuticular lesions on appendages and general body surfaces were also observed. Cadmium collected by hemocytes and accumulated in gills may be sloughed during post-treatment. Shrimp that survived Cd exposures and were placed in Cd-free water sloughed blackened portions of branchia, with normal appearance within 14 days. When *P. vulgaris* were exposed to 0.075 mg Cd/l for 10 days, gill lamellae were blackened, necrotic and distended due to congestion with larger numbers of hemocytes. When *Artemia* containing Cd were used as food, transfer of Cd to *P. vulgaris* was much less efficient than transfer directly from water. To produce equivalent whole body residues in shrimp, about 15,000 times more Cd must be introduced in food than could be obtained from seawater.

2428. Noel-Lambot, F. and J.M. Bouquegneau. 1977. Comparative study of toxicity, uptake and distribution of cadmium and mercury in the sea water adapted eel *Anguilla anguilla*. Bull. Environ. Contamin. Toxicol. 18:418-424.

Mortality of seawater adapted eels reached 100% in 5 hrs during immersion in 10 mg Hg/l, in 20 days in 1 mg Hg/l, in just over 10 hrs in 200 mg Cd/l, and in 6 days in 50 mg Cd/l. After 15 days, mortality was 25% in 0.1 mg Hg/l and 50% in 30 mg Cd/l. Distribution of cadmium in eels exposed to 0.13 mg Cd/l for 60 days was 16 mg/kg wet wt in kidneys, 6 in digestive tract, 4 in liver, and <2 in other organs; total body concentration was 0.6 mg Cd/kg wet wt. Muscle contained 27% of total body Cd, digestive tract 25%, and kidneys 20%. Eels exposed to 0.1 mg Hg/l for 32 days had 116 mg Hg/kg dry wt in kidneys, 110 in spleen, 67 in gill filaments, 48 in liver, and 19 to 13 in other organs. Total body concentration was 15 mg Hg/kg wet wt; muscle contained 66% of total body Hg, and skin 13%.

2429. O'Conner, J.S. 1975. Contaminant effects on biota of the New York Bight. *In*: Proc. Gulf Caribbean Fish. Instit. 28th Annual Session, Bal Harbour, Fla.: 50-63.

Annual quantities of contaminants reaching the New York Bight include 3,940 to 32,000 metric tons from atmospheric fallout of Cd, Cr, Cu, Fe, Pb, and Zn, plus a variety of sources of municipal and industrial sludge, wastewater, and runoff. Examples of impact on marine resources include a high prevalence of diseases in fish and crustaceans; major alterations in distribution and abundance of bottom living organisms away from local bays; widespread distribution in exceptionally high numbers of coliform and fecal coliform bacteria, indicative of pathogenic bacteria, leading to closure of clam fishery operation; presence of transfer-resistant (R^+) bacteria which are relatively insensitive to a broad spectrum of heavy metals and antibiotics; and noxious concentrations of suspended particulate material, flotsam and surface slicks.

2430. Oduleye, S.O. 1976. The effects of hypophysectomy, prolactin therapy and environmental calcium on freshwater survival and salinity tolerance in the brown trout *Salmo trutta* L. Jour. Fish. Biology 9:463-470.

Hypophysectomy resulted in a loss of ability of the euryhaline brown trout to survive in freshwater. The mean survival time was 4-5 days. Maintenance in a medium containing 5 mM calcium increased the mean survival time to 8 days while 10 mM decreased it. Injection of 0.2 I.U./gm prolactin enabled hypophysectomized fish to survive the 2-week duration of the experiment. High environmental calcium, or pre-adaptation to a medium of high calcium, increased salinity tolerance of the brown trout probably by promoting a quick return of plasma electrolyte concentration to normal after transfer to seawater.

2431. Okazaki, R.K. 1976. Copper toxicity in the Pacific oyster, Crassostrea gigas. Bull. Environ. Contamin. Toxicol. 16:658-664.

Oysters were exposed to copper levels of 0.10, 0.25, 0.50, 0.75, or 1.00 mg/l for three separate 96-hr intervals at 12-15 C and 33 o/oo S. One 336-hr exposure to Cu concentrations of 0.010, 0.025, 0.050, 0.075, or 0.100 mg/l was performed to test sublethal effects. The 96 hr LC-50 was 0.56 mg/l; all deaths occurred after 72 hrs. However, at 1.00 mg Cu/l oyster mortality averaged 67%. Thus, the LC-50 may represent the upper limit of response to lower but lethal concentrations of Cu^{2+}. Copper at 1.00 mg/l may become biologically unavailable due to precipitation, but oysters may also be able to sense this chemical form and cease feeding by closing their valves. The author's preliminary experiments show 100% survival of oysters exposed to 5.6 and 7.5 mg Cu/l for 96 hrs. In the 336 hr test, oysters survived all concentrations without reaching 50% mortality. Survival ranged from 60-80% and death first appeared after 144 hrs.

2432. Olsson, M. 1976. Mercury level as a function of size and age in northern pike, one and five years after the mercury ban in Sweden. Ambio 5:73-76.

Mercury levels in muscle of Esox lucius collected from a lake previously polluted by a papermill in central Sweden decreased after mercury discharge from the mill ceased. Several fish in 1968 contained >5.0 mg Hg/kg wet wt. In 1972, all fish contained < 4.0 mg Hg/kg. Of five tested parameters of size, length was best with positive correlation coefficients with Hg levels of 0.67-0.77. Male pike, which grow more slowly, had significantly higher Hg levels in muscle than females. Males of different ages but the same length showed similar Hg accumulation. Correlation between Hg levels and condition factor was weakly negative; during starvation, mercury levels in pike seemed to increase. Author suggests that size of fish or metabolic Hg turnover role should be of prime interest in prediction of fish mercury levels.

2433. Pace, F., R. Ferrara, and G. Del Carratore. 1977. Effects of sublethal doses of copper sulfate and lead nitrate on growth and pigment composition of Dunaliella salina Teod. Bull. Environ. Contamin. Toxicol. 17:679-685.

Concentrations of 0.5, 1.25, or 2.5 mg Cu/l added as copper sulfate inhibited growth of the green flagellate Dunaliella salina over 31 days; number of cells was always lower than controls. No growth was recorded at 5.0 mg Cu/l. Sublethal Cu concentrations retarded onset of logarithmic growth phases. In 2.5 mg Cu/l, this growth phase occurred after 18 days, compared to 3 days for controls. Lead nitrate, at 0.3 mg Pb/l, slightly inhibited culture growth, while 0.9, 4.5, and 15.0 mg Pb/l significantly reduced algal growth after day 16. Addition of Pb^{2+} as lead chloride produced similar results. Normal Dunaliella cells undergo pigment content reduction during rapid logarithmic growth. In Cu-treated cells, growth was slower and pigment content reached higher values, up to 14.9×10^{-9} mg/cell in 2.5 mg Cu/l at 12 days, before decreasing. However, total pigment content of culture generally decreased with increasing concentrations of both metals. Carotenoid content of cells in 4.5 and 15.0 mg Pb/l increased compared to controls. An increase in carotenoid pigments is normally associated with a general decrease of nutrients in the medium.

2434. Palmer, J.B. and G.M. Rand. 1977. Trace metal concentrations in two shellfish species of commercial importance. Bull. Environ. Contamin. Toxicol. 18:512-520.

In fall 1974, spring 1975, and summer 1975, the scallop Placopecten magellanicus and quahaug Arctica islandica were collected from the Continental Shelf south of Long Island and analyzed for metal content. Concentrations, in mg/kg wet wt, for P. magellanicus ranged from 0.8 to 8.7 for cadmium, 0.2 to 2.4 for chromium, 0.3 to 3.0 for copper, 0.4 to 2.2 for lead, <0.1 to 0.3 for mercury, <0.5 to 3.3 for nickel, and 9.3 to 24.0, with a high of 109.0, for zinc. In A. islandica, values ranged from <0.06 to 0.9 for Cd, 0.3 to 2.5 for Cr, 0.1 to 3.8 for Cu,

<1.0 to 2.6 for Pb, 0.1 to 1.2 for Hg, 1.1 to 7.0 for Ni, and 2.4 to 25.8 for Zn. Mean Cd level was 7.5X higher in *P. magellanicus* than in *A. islandica*; for all other metals *P. magellanicus* contained equal or lower average amounts.

2435. Parker, J.I., H.L. Conway and E.M. Yaguchi. 1977. Dissolution of diatom frustules and recycling of amorphous silicon in Lake Michigan. Jour. Fish. Res. Bd. Canada 34:545-551.

Levels of diatom frustules and amorphous silicon per kilogram of dry sediment were measured at 5 m intervals in the upper water column (0-40 m), in sediment traps at 37 and 60 m below the surface, and in a sediment core. The average concentration of frustules/kg of dry sediment in the water column was 3.14×10^5. Mean levels at 37 and 60 m were 1.16×10^5 and 5.03×10^4 frustules/kg dry sediment, respectively. Subsamples from the sediment core averaged 6.31×10^3 frustules/kg dry surficial sediment. The average proportion of amorphous silicon/kg dry sediment was 0.009% in the water column, 0.008% in the 37 m traps, 0.006% in the 60 m traps and < 0.002% in subsamples from the sediment core. The major fraction of amorphous silicon produced annually as diatom frustules was decomposed before incorporation in the permanent sediment. A comparison of the annual silicon requirement for diatom production and silicon inputs showed that the watershed contributed <5.0% of the dissolved reactive silicon required for annual diatom production. These observations suggest that recycling of biogenic silicon provides the major source of soluble reactive silicon required for diatom blooms in Lake Michigan.

2436. Parker, J.I., H.L. Conway and E.M. Yaguchi. 1977. Seasonal periodicity of diatoms, and silicon limitation in offshore Lake Michigan, 1975. Jour. Fish. Res. Bd. Canada 34:552-558.

Seasonal distributions of soluble reactive silicon and diatom biomass show a strong relationship. Diatom biomass maxima occurred in spring and fall and produced a bimodal bloom sequence. As the spring bloom progressed, the diatom accumulation rate declined and soluble reactive silicon was reduced from 0.013 to 0.007 mmole/l. In summer, after the bloom, silicon was at a minimum of 0.001 mmole/l and diatom biomass was also at seasonal minima. Diatom biomass increased again in October when silicon supplies were replenished and the concentration exceeded 0.007 mmoles/l. A critical silicon concentration of approximately 0.006 mmoles/l may control the development and timing of offshore diatom populations in Lake Michigan.

2437. Parvaneh, V. 1977. A survey of the mercury content of the Persian Gulf shrimp. Bull. Environ. Contamin. Toxicol. 18:778-782.

Mercury levels in 100 samples of Persian Gulf shrimp ranged from 0.08 to 0.88 mg/kg wet wt with a mean of 0.24 mg/kg. Eight percent of these samples taken from different fishery stations and retail shops showed mercury content above 0.5 mg/kg. In most samples the value was below 0.3 mg/kg.

2438. Pascoe, D. and D.L. Mattey. 1977. Studies on the toxicity of cadmium to the three-spined stickleback Gasterosteus aculeatus L. Jour. Fish Biology 11:207-215.

Cadmium was lethal to sticklebacks at all concentrations tested between 100.0 and 0.001 mg Cd/l, with an LC-50 (96 hr) at 23 mg Cd/l. Median period of survival in minutes was 48,000 at 0.001 mg/l; 23,500 at 0.01 mg/l; 11,000 at 0.1 mg/l; 19,200 at 1 mg/l; 2,800 at 10 mg/l and 413 mins at 100 mg/l. The pattern of mortality shown by a time-concentration curve suggests that toxicity is not due to a single mechanism but changes with concentration. Unusual swimming behavior was associated with high Cd levels. Fish accumulated Cd with whole body levels increasing from 0.90 mg/kg wet wt at 0.001 mg Cd/l exposure concentration to 51.0 mg/kg at 100 mg Cd/l. The concentration factor decreased with increasing exposure concentration from 0.51 at 100 mg/l to 511 at 0.001 mg/l. The plerocercoid parasite Schistocephalus solidus in the host's perivisceral cavity contained at least 50% less cadmium than the tissue of its host.

2439. Patrick, F.M. and M.W. Loutit. 1977. The uptake of heavy metals by epiphytic bacteria on Alisma plantago-aquatica. Water Research 11:699-703.

Epiphytes of the bacteria Sphaerotilus on the surface of the freshwater plant Alisma plantago-aquatica collected from a polluted river were a major factor contributing to the total metal concentrations of the plant. Estimations of metal concentrations in mg/kg dry wt in young leaves of Alisma with epiphytes (and without) were: 2.6 (1.9) for Cr, 155 (70) Cu, 1306 (1514) Mn, 1145 (864) Fe, 14 (14) Pb, and 119 (98) for Zn. Removal of epiphytes from leaf surface of young and old plants resulted in significant reductions in levels of Cr (reduced by 15-50%), Cu (30-35%), and Fe, Pb, and Zn (10-50%). Increases in total metal concentration of leaves were paralleled by similar increases in percentage of Cu and Zn retained in epiphytes of young leaves. Both the numbers of epiphytes and total concentrations of Cr, Pb and Zn of plants increased in polluted water. These observations indicate that absorption of metals by Alisma roots provides a basal level of metals in plant tissues, and that these levels are subject to plant metabolic requirements, sediment metal concentrations, and supplementation by absorption of metals from water by epiphytic bacteria. Amount of metal absorbed by root systems and by epiphytes appeared to increase by the same degree in polluted water. Levels of metals in the sediments in mg/kg dry wt were: 10-64 Cr, 140-286 Cu, 45-130 Mn, 649-1593 Fe, 53-79 Pb, and 100-345 for Zn.

2440. Patterson, C. and D. Settle. 1977. Comparative distributions of alkalies, alkaline earths, and lead among major tissues of the tuna Thunnus alalunga. Marine Biology 39:289-295.

Concentrations of potassium, rubidium, cesium, calcium, strontium, barium, and lead in various tissues of tuna caught off San Diego, California were determined. Potassium, Rb, and Cs were all distributed uniformly throughout the organs, muscles, and skeleton, with 900 to 6,800 mg/kg of K wet wt being the most prevalent of the three. The skeleton contained 95% of the Ca and Sr, and 70% of the Ba and Pb, while 80% of the K, Rb, and Cs are in muscle, as percent of total body metal in the organ. Smaller amounts of Cs, Ba, and Pb are associated with the nutrient metals K and Ca in marine animals compared to terrestrial animals. This difference is a result of the purity of K and Ca in seawater and the smaller amounts of trace metals associated with them compared to the impurity of K and Ca in terrestrial rocks. Food-chain enhancement and depletion of metals can be evaluated by comparing ratios of trace metals to abundant nutrient metals in seawater and tuna. Cesium, for example, is enriched relative to K, in going from seawater to tuna, by a factor of 13; Sr and Ba are both depleted by factors of 5 relative to Ca; and Pb is enriched relative to Ca by a factor of 14.

2441. Pearse, J.B. 1977. Report to the working group on pollution baseline and monitoring studies in the Oslo Commission and ICNAF areas on heavy metals in selected finfish and shellfish from the northwest Atlantic. International Council for the Exploration of the Sea. Fisheries Improvement Committee. C.M. 1977/E:34. 97 pp.

Concentrations of Ag, As, Cd, Cr, Cu, Mo, Ni, and Pb in fish, elasmobranchs, crustaceans, and molluscs from the northwest Atlantic were tabulated. Other than mercury, no samples contained mean levels of metals which exceeded values considered harmful for human consumption. Some demersal species, such as dogfish and marlin, contained individual Hg levels that exceeded 0.5 mg/kg wet wt "action levels". Possible relationships between size of fish, geographic area of catch, species, or feeding behavior and metal concentrations have not been confirmed.

2442. Pentreath, R.J. 1976. The accumulation of mercury by the thornback ray, *Raja clavata* L. Jour. Exp. Mar. Biol. Ecol. 25:131-140.

Maximum mercury concentration occurring naturally in 30 g rays from Suffolk, England was 0.22 mg/kg wet wt in blood cells, making up 2.0% of total body Hg. Gut and gill filaments of this elasmobranch contained 0.16 and 0.13 mg/kg, respectively, making up 10.4 and 4.5% total body Hg. Muscle, with 0.05 mg/kg, had the highest proportion of body Hg with 59.5%. Blood plasma had only 0.001 mg/kg, 0.04% total body Hg. Concentration factor of Hg-203 in rays over that in Hg-203 Cl_2 labelled seawater (5 x 10^{-11} mCi/l) rose to 40 in 4 days, and to 500 in 64 days. Loss of Hg-203 after 74 days was $<20\%$. Concentration factor in rays, using CH_3Hg-203 Cl seawater, increased linearly from 0 to 1100 in 85 days. Maximum mean concentration of Hg-203/blood plasma from 5 x 10^{-11} mCi/l Hg-203 Cl_2 labelled seawater was 81 in gill filaments. Other high values were rectal gland 70, spleen 58, and kidney 54. Minimum levels were blood cells 9, muscle 7 and cartilage 3. These concentrations after 91 days loss were gill filament 96, rectal gland 86, spleen 73, kidney 71, blood cells 12, muscle 10, and cartilage 6 . Accumulation for 91 days of Hg-203 from CH_3Hg-203 Cl seawater produced Hg-203/blood plasma values of 42 for rectal gland, gill filaments 34, liver 32, heart 28, and 6 for cartilage. Concentrations after 74 days loss were gill filaments 37, liver 30, muscle 29, rectal gland 29, blood cells 7, and gonad 5. Retention of

Hg-203 5 to 8 days after rays were fed labelled *Nereis* worms was only 8.6-20.3% from Hg-203 Cl_2 and 94.0-99.5% from CH_3Hg-203 Cl. After 35 days, retention was only 15-6% from Hg-203 Cl_2 and 90% from CH_3Hg-203 Cl. Distribution, as Hg-203 concentration/plasma, in organs was 340 for stomach, 37 kidney, 27 liver, 1 muscle and 0.9 cartilage from *Nereis* fed Hg-203 Cl_2. From CH_3Hg-203 Cl, values ranged from 85.6 for heart, 68.7 muscle, 54.5 liver, 43.0 blood cells, to 5.9 for cartilage.

2443. Pentreath, R.J. 1977. The accumulation of arsenic by the plaice and thornback ray: some preliminary observations. International Council for the Exploration of the Sea. Fisheries Improvement Committee. C.M. 1977/E:17. 11 pp.

Accumulation of As-74, as sodium arsenate, from seawater and from labelled food by plaice, *Pleuronectes platessa*, and rays, *Raja clavata*, was compared. Uptake from seawater, with 0.001-0.003 mg As/l and 0.001 mCi/l as tracer, was slow and resulted in uniform labelling of all internal organs after 42 days. Concentration factor of As in plaice eggs was only 0.6 after 14 days, while larvae had CF of 2 after 8 days. Retention of As-74 from labelled polychaete worms, *Nereis* sp., as food was 85% for the ray 10 days later, but was 10% for the plaice. Both species contained the largest fraction of As-74 in muscle, 75% in rays on day 45 and 95% in plaice on day 35, although rays also had high concentrations in kidney.

2444. Pesch, G., B. Reynolds and P. Rogerson. 1977. Trace metals in scallops from within and around two ocean disposal sites. Marine Poll. Bull. 8:224-228.

Concentrations of iron, copper, chromium, aluminum, silver, manganese, lead, cobalt, nickel, vanadium, cadmium, zinc and titanium were determined in sea scallops *Placopecten magellanicus* collected from the vicinity of two ocean disposal sites off the U.S. mid-Atlantic coast. Mean metal concentrations, in mg/kg dry wt, in soft tissues were: Ag 1.8; Al 338.0; Cd 20.9; Co 0.5; Cr 3.0; Cu 7.3; Fe 803.0; Mn 29.8; Ni 4.4; Pb 3.64; Ti 9.8; V 28.5; and Zn 105.0. Patterns of metals distribution show that Ag, Cu, Ni, Cd, and V may be used as tags for individual wastes disposed at the two sites; that disposed material are transported by currents south and southwest from disposed sites; and that biological availability and potential toxicity of some metals pose a threat to marine biota.

2445. Phillips, D.J.H. 1977. Effects of salinity on the net uptake of zinc by the common mussel *Mytilus edulis*. Marine Biology 41:79-88.

Net uptake of chloride salts of zinc, cadmium and copper by mussels at 35 o/oo salinity and under a fluctuating salinity range between 35 and 15 o/oo was determined. Mussels subjected to a mixture, in mg/l, of 0.5 Zn, 0.05 Cd, and 0.1 Cu for 5 days showed mean concentrations in mg/kg dry wt soft parts as follows:

Salinity Regime	Zinc	Cadmium	Copper
Control, 35 o/oo (start)	258	9.7	7.5
Control, 35 o/oo (Day 5)	233	10.0	6.9
5 Days, 35 o/oo	431	20.0	33.8
5 Days, 35→28 o/oo	426	—	—
5 Days, 35→22 o/oo	542	28.8	78.0
5 Days, 35→15 o/oo	409	—	—

Two groups of mussels, one from Western Port Bay, Australia, with salinity range 35 to 36 o/oo and another from Port Phillip Bay with salinity range 8.5 to 33.5 o/oo, were exposed to sublethal concentrations of zinc chloride of 1.0, 0.8, 0.4 mg/l for 13 days at 35 o/oo salinity. Maximum concentrations for zinc, in mg/kg dry wt. were as follows:

Location	Nominal ZN Concentration (mg/l)	Zn, in mg/kg dry wt Exp I	Exp II
Port Phillip Bay	0.4	1167	629
	0.8	1215	776
	1.0	1241	945
Western Port Bay	0.4	474	591
	0.8	537	703
	1.0	629	742

Because salinity affects zinc uptake by mussels under conditions of stress, this factor should be considered when mussels are used as indicators of environmental zinc levels.

2446. Phillips, D.J.H. 1977. The common mussel *Mytilus edulis* as an indicator of trace metals in Scandinavian waters. I. zinc and cadmium. Marine Biology 43:283-291.

Concentrations of zinc in mg/kg dry wt whole soft parts of mussels from 54 locations in Scandinavia ranged from 14-460; for cadmium this range was 0.4-12.9. Local variations in concentrations of the two metals found in samples taken close to industrial sources of zinc and cadmium confirmed the ability of mussels to act as accurate indicators of pollution by these metals over the entire range of salinities in which this species can exist. In addition, offshore samples remote from industrial discharges revealed higher concentrations of Zn and Cd in mussels from low-salinity areas than mussels from high-salinity areas. Major decreases in metal concentrations in mussels were apparent in regions of the Sound and Great Belt, which are areas of rapid salinity change due to mixing of Baltic water with water from the Kattegat. Comparison of these results with those reported for zinc and cadmium in water throughout the study area suggested the existence of a higher biological availability of these metals in regions of low salinity.

2447. Phillips, D.J.H. 1977. The use of biological indicator organisms to monitor trace metal pollution in marine and estuarine environments--a review. Environmental Pollution 13:281-317.

Use of biological indicator organisms to define areas of trace metal pollution appears more attractive than water or sediment analysis, as these organisms not only concentrate metals from water, allowing inexpensive and relatively simple analysis, but they may also represent a moving time-averaged value for relative biological availability of metals at each site studied. The present state of knowledge on use of indicator organisms to study trace metal pollution is reviewed, with emphasis on macroalgae, bivalve molluscs, and teleosts, but also includes barnacles and decapod crustaceans, limpets, and polychaetes. Data is presented for Ag, As, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb, and Zn. It is suggested that macroalgae and bivalves are the most efficient and reliable indicators at present. It is further suggested that effects of sampling and environmental variables have been largely overlooked, and that further field and laboratory studies are necessary before results of surveys using biological indicator organisms can be relied upon.

2448. Pickering, Q., W. Brungs and M. Gast. 1977. Effect of exposure time and copper concentration on reproduction of the fathead minnow (Pimephales promelas). Water Research 11:1079-1083.

The chronic effect of prespawning exposure to various concentrations of copper on minnow reproduction was determined. Copper was introduced 6, 3 and 0 months prior to spawning at concentrations ranging from 4.2 (control) to 98 ug/l. Survival was not affected by copper at any of the chronic exposure levels. Prespawning copper exposure time had no significant effect on reproduction. Number of eggs produced per female decreased at copper levels of 37 ug/l and higher. Final length of females exposed to 60 and 98 mg Cu/l for 6 months was significantly lower than controls; final weight was significantly lower after 6 month exposure to 98 ug/l. The LC-50 (96 hr) values were 490 ug Cu/l for 6-week-old fry and 460 ug/l for 6 month old subadult fish. Maximum acceptable toxicant concentration (MATC) was estimated to be 32 0 ug/l and the EC-50 for egg production (eggs per female) as compared to controls was 41.7 ug/l.

2449. Price, H.H., II, C.T. Hess, and C.W. Smith. 1976. Observations of Crassostrea virginica cultured in the heated effluent and discharged radionuclides of a nuclear power reactor. Proc. Nat. Shellfish. Assn. 66:54-68.

American oysters were grown on rafts for 26 months at 4 sites in effluent waters near the Maine Yankee Nuclear Power Reactor in Montsweag Bay from 1973 to 1975. At the closest site, accumulation of Co-58 and Mn-54 both reached 10^{-6} mCi/kg live wt. Uptake of radionuclides and growth of oysters were accelerated at warmer water sites. Calculations from the pulse driven relaxator model described amplitude and time variation of Co-58 and Mn-54 concentrations in the field study better than an existing concentration factor model.

2450. Prabhu, N.V. and M.K. Hamdy. 1977. Behavior of mercury in biosystems. I. uptake and concentration in food-chain. Bull. Environ. Contamin. Toxicol. 18:409-417.

Mercury was followed through 3 trophic systems: bacteria Bacillus licheniformis; larvae of mosquito Aedes aegypti; and guppy Lebistes reticulatus, using Hg-203 as mercuric nitrate or phenylmercuric acetate. In 0.11 mg Hg-203/kg medium in inorganic (nitrate) form, maximum uptake by bacteria at 23 C was 54% of total Hg in media after 72 hr incubation. At 37 and 45 C, maximum uptake was achieved at 24 hr at 78 and 66%, respectively. In 0.11 mg/kg organic Hg-203, uptake was highest in 45 C, at 66% after 72 hrs. Concentration factor of Hg in bacteria over media increased with time of incubation for both inorganic and organic forms of Hg-203, with maximum values reached within 24 to 72 hr. The highest CF was 78 with inorganic Hg at 37 C after 72 hr. Higher CF values were obtained for inorganic as compared to organic Hg at all incubation temperatures, and values at 23 C were always lower than those at 37 or 45 C. Hg uptake in mosquito larvae, aged 3, 5, and 7 days, rose steadily in all cases to a maximum of 14-17% at day 96, in 0.022 mg Hg-203/l as inorganic Hg. In organic Hg, uptake was highest at 72 hr, being 20% for 7 day old larvae, 15% for 5 day old, and 13% for 3 day old; all values declined at later incubation times. CF of Hg in larvae over water was a maximum at 72 hr in organic Hg for all 3 age groups, ranging from 381 to 579, and was a maximum at 96 hr in inorganic Hg, ranging from 95 to 130. Values increased as age of larvae increased. Uptake of Hg by guppies in 0.015 mg Hg-203/l peaked at 24% on hour 48 for organic and on hour 72 for inorganic Hg. CF in guppies over water was higher for organic Hg. Maximum value for the organic form was 275 at 48 hr which then decreased, while for inorganic form was 175 at 72 hr before decreasing.

2451. Ramamoorthy, S., S. Springthorpe, and D.J. Kushner. 1977. Competition for mercury between river sediment and bacteria. Bull. Environ. Contamin. Toxicol. 17:505-511.

Uptake of mercury by bacteria, Pseudomonas fluorescens, and by clay sediment was studied in bags suspended in Ottawa River water with 1.45 mg Hg/l added as $Hg(NO_3)_2$. By 25 hrs, bacteria contained 1000 mg Hg/kg dry wt, and at 72 hrs, almost 1300. Hg concentration in sediment did not reach 100 mg/kg dry wt by 72 hrs. The thick suspension of bacteria had a much greater binding capacity than sediment, which normally provides a very efficient sink. When clay sediment was preloaded with 400 mg Hg/kg, and washed to remove unadsorbed material, bacteria accumulated 0.45 mg Hg/kg dry wt by 4 hrs, and increased to 1.5 at 96 hrs. Bacteria removed Hg from sediment even with two dialysis membrane barriers between them.

2452. Rawlence, D.J. and J.S. Whitton. 1977. Elements in aquatic macrophytes, water, plankton, and sediments surveyed in three North Island lakes. New Zealand Jour. Marine Freshwater Res. 11:73-93.

Aquatic macrophytes *Elodea canadensis*, *Lagarosiphon major*, *Potamogeton crispus*, *P. ochreatus*, *P. cheesemanii*, and *Myriophyllum elatinoides* were collected from lakes in New Zealand and analyzed for 26 elements. Data was provided on variability within a single strand, and change in element content during seasons and stages of growth. Surface water, plankton, and sediment samples were also collected and analyzed for the same elements. Average composition, in mg/kg dry wt, of plankton, mainly phytoplankton, was high for Si (160,000), Ca (13,000), Na (10,000), Al (5,400), K (5,300), Mg (5,200), Fe (2,600), Mn (420), and Ba (260). Zn, Cu, Co, Mo, Ni, V, Sr, Cr, and Pb levels were all < 100 mg/kg. Content of N, P, S, Cl, Ti, B, Ga, and Zr was also determined. Average levels of Mg (5,800 mg/kg), Mn (5,800), Na (5,800), Fe (710), B (33), V (9.2), and Cr (5.0) and P and Cl were highest in macrophytes from Lake Rotoaira, which apparently has a higher nutrient level than the other lakes. Maxima also reflect differences in catchment geology between the three lakes.

2453. Reeve, M.R., J.C. Gamble, and M.A. Walter. 1977. Experimental observations of the effects of copper on copepods and other zooplankton: controlled ecosystem pollution experiment. Bull. Marine Science 27:92-104.

Ingestion, filtration, and fecal pellet production rates of the copepods *Pseudocalanus* sp. and *Calanus* sp. generally decreased as ambient seawater increased in copper concentration at levels of 0.000, 0.005, and 0.010 mg/l. Origin of food (contaminated or not) affected these rates. Feeding rates of *Euphausia pacifica* and the ctenophore *Pleurobranchia bachei* at both 0.005 and 0.010 mg Cu/l levels were between 45 and 70% of control values. Egg production varied widely between animals in different concentrations, while fecal pellet production remained similar at all Cu levels, based on sediment trap data. Population control by predation and grazing is also discussed.

2454. Reeve, M.R., M.A. Walter, K. Darcy, and T. Ikeda. 1977. Evaluation of potential indicators of sub-lethal toxic stress on marine zooplankton (feeding, fecundity, respiration, and excretion): controlled ecosystem pollution experiment. Bull. Marine Science 27:105-113.

Small copepods representing *Acartia*, *Pseudocalananus*, *Paracalanus*, *Temora* and *Oithona* genera from three different locations were exposed to 0.00, 0.01, 0.02, 0.05, or 0.10 mg/l copper for up to 7 days. These generally showed a decrease in fecal pellet and egg production with increasing copper concentrations. A similar trend was evident for copepods exposed to 0.00, 0.002, or 0.01 mg/l mercury for up to 10 days. LC-50 (48 hr) concentrations were 0.032 mg/l for Hg, 0.105 mg/l for Cu, and 0.017 mg/l for a Hg-Cu mixture. Authors state that although effects could be demonstrated in the 0.001-0.01 mg/l range, many biological and chemical factors combined to make it pointless to specify toxicity levels more precisely, particularly where the aim is to extrapolate data to other situations for regulatory purposes. Species composition, season, temperature, and chemical complexing capacity of the water would all introduce variability. It is suggested that at this concentration range, chemical species present may be less important than total amounts. Respiration and excretion rates of zooplankton were not sensitive indicators of metal stress under test conditions.

2455. Reish, D.J. 1977. Effects of chromium on the life history of *Capitella capitata* (Annelida: Polychaeta). *In:* Vernberg, F.J., A. Calabrese, F.P. Thurberg, and W.B. Vernberg (eds.). Physiological Responses of Marine Biota to Pollutants. Academic Press, N.Y.: 199-207.

Effects of hexavalent chromium at levels of 0.025, 0.05, 0.1, 0.2, and 0.4 mg/l on life cycles of the worm *Capitella capitata* were determined over a five month period. In controls and two lowest concentrations, 82-95% of the worms survived, 58 and 57% survival in 0.1 and 0.2, respectively, and 21% in 0.4 mg Cr/l. In concentrations of 0.1 mg Cr/l and lower, 31 to 40 females reproduced, at the two highest concentrations only 3 to 4 females deposited ova. Average numbers of offspring from females in <0.1 mg Cr/l was 243-279; this decreased significantly at Cr levels of 0.1 mg/l and higher, to 144-174 larvae. Percent occurrence of abnormal larvae increased from 0.0 to 1.7 as Cr concentration increased to 0.4 mg/l. Abnormal metatrochophore larvae had bifurcated posterior ends and aberrant swimming behavior.

2456. Reish, D.J. and R.S. Carr. 1978. The effect of heavy metals on the survival, reproduction, development, and life cycles for two species of polychaetous annelids. Marine Poll. Bull. 9:24-28.

Effects of exposure to heavy metals on survival and reproduction of two polychaetes *Ctenodrilus serratus* and *Ophryotrocha diadema* were measured at concentrations of 0.1-10.0 mg/l for Cd, 0.05-50.0 for Cr, 0.01-1.0 for Cu, 0.1-20.0 for Pb, 0.001-0.5 for Hg, and 0.05-20.0 for Zn. Reduction in number of the original 40 specimens of *Ctenodrilus* after 96 hrs occurred at 5.0 mg Cd/l, down to 13, and 10.0 mg Cd/l, with none left; at 5.0 mg Cr/l, down to 13; at 0.25 mg Cu/l, 30 left, 0.5 Cu with 1 left, and 1.0 Cu with none remaining; at 0.05 mg Hg/l, down to 15, and 0.1 and 0.5 Hg with none; and at 10.0 mg Zn/l, down to 34, and 20.0 with none left. Thirty-six remained at 20.0 mg Pb/l. Population size of *Ctenodrilus* increased slightly after 21 days in lower concentrations of Cd, Cu, and Hg. Reproduction was significantly suppressed in ≥2.5 mg Cd/l, all levels of Cr, ≥0.1 mg Cu/l, ≥1.0 mg Pb/l, ≥0.05 mg Hg/l, and ≥0.5 mg Zn/l. All worms were dead after 21 days in the highest concentrations of each metal. Reduction in the 40 original specimens of *Ophryotrocha* after 96 hrs was as follows: in 5.0 mg/l Cd to 11 and 10.0 Cd to 0; in 0.25 mg Cu/l to 5, and 0.5 and 1.0 Cd to 0; in 5.0 mg Pb/l to 34, 10.0 Pb to 22 and 20.0 to 17; in 0.05 mg Hg/l to 35, 0.1 Hg to 16 and 0.5 Hg to 0; and in 1.75 mg Zn/l to 8 and 2.5 Zn to 0. Thirty-nine specimens still remained in 5.0 mg Cr/l. Population size of *Ophryotrocha* increased slightly over 21 days in lower concentrations of Cd, Cu, Pb, Hg, and Zn. Reproduction was significantly suppressed in ≥1.0 mg/l for Cd and Cr, ≥0.25 mg Cu/l, ≥5.0 mg Pb/l, ≥0.1 mg Hg/l, and ≥0.5 mg Zn/l. Except for populations exposed to Pb, all worms were dead after 21 days in the highest metal concentrations. Suppression of reproduction for both worms generally occurred at levels 100X less than LC-50 (96 hr) values.

2457. Robertson, J.D. 1953. Further studies on ionic regulation in marine invertebrates. Jour. Exper. Biol. 30:277-296.

Blood or coelomic fluid was analysed for Ca, Mg, Na and K in echinoderms, sipunculids, molluscs, and crustaceans to determine extent of ionic regulation. Little regulation is shown by the echinoderm *Holothuria*; however, the bivalves *Ostrea* and *Mytilus* regulate K, up to 135% of seawater concentrations. The nudibranch *Archidoris* accumulates K at 128%, Ca at 132%, and Mg at 107%, while the sipunculid *Plascolosoma* has lower Mg. (69%) but higher Na (104%). The cephalopod *Sepia* regulates all examined ions except Mg. Values, as % concentration in dialysed plasma, were Na 92-94%, Ca 84-97%, K 193-223%, and Mg 97-100%. Vitreous humour of the cephalopod eye in *Sepia*, *Loligo*, and *Eledone*, may have only 10-20% Mg but >115% Na of concentrations in plasma dialysate. Decapod and stomatopod crustaceans studied regulated all ions, ranges being Mg 32-99%, Ca 84-137%, Na 97-111%, and K 120-156%. *Portunus*, *Eupagurus*, and the stomatopod *Squilla* show more regulation than *Dromia* and spider crabs *Maia* and *Hyas*. In *Pachygrapsus*, plasma ions are maintained below equilibrium values, especially Mg at 24%; total ions are 1,163 mg/kg water compared with 1,353 in seawater. An inverse relationship existed between degree of activity and Mg blood content in 16 species of crustaceans; more active species have lower Mg concentrations. Levels of Cl, SO_4 and NH_4 were also considered in ion regulation studies of these invertebrates.

2458. Robinson, A.V., T.R. Garland, G.S. Schneiderman, R.E. Wildung, and H. Drucker. 1977. Microbial transformation of a soluble organoplutonium complex. *In*: Drucker, H. and R.E. Wildung (eds.). Biological implications of metals in the environment. ERDA Symp. Ser. 42: 52-62. Avail. as CONF-750929 from Nat. Tech. Inf. Serv., U.S. Dept. Comm., Springfield, VA 22161

Plutonium-resistant fungi, from a Ritzville silt loam, were grown in liquid culture containing $Pu_2(DTPA)_3$ for about 10 days. This organism was capable of transporting Pu into the cell and modifying the original organoplutonium complex, as shown by chromatographic and electrophoretic behavior. The several Pu-containing intra- and exocellular components, which differed from $Pu_2(DTPA)_3$, exhibited a negative charge and globular protein equivalent molecular wts < about 3000.

2459. Robohm, R.A. and M.F. Nitkowski. 1974. Physiological response of the cunner, *Tautogolabrus adspersus*, to cadmium. IV. effects on the immune system. *In*: U.S. Dept. Comm. NOAA Tech. Rept. NMFS SSRF-681:15-20.

Two elements of the immune system in cunners were examined after 96-hr exposure to cadmium: 1) clearance of intracardially injected bacteria from the bloodstream and 2) ability to produce antibody against intraperitoneally injected sheep red blood cells (SRBC). Exposure to 12 mg/l cadmium increased the rates of bacterial uptake in phagocytes of liver and spleen but significantly decreased rates of bacterial killing within these cells. Exposure of fish at 3 to 24 mg/l cadmium failed to influence antibody production against SRBC. All fish injected with 48 mg/l of cadmium died within two weeks post-treatment. Authors suggest that Cd in cunners may increase susceptibility to infection.

2460. Roegge, M.A., W.P. Rutledge, and W.C. Guest. 1977. Chemical control of *Zoothamnium* sp. on larval *Macrobrachium acanthurus*. *Aquaculture* 12:137-140.

Ten chemicals were tested for ability to control outbreak of *Zoothamnium* ciliates on larval crustaceans, *M. acanthurus*. After 24 hrs in 0.5 mg/l copper sulfate, 5 to 10% of *Zoothamnium* were removed, while larvae had poor movement and color. In 5.0 mg/l potassium permanganate, <5% of *Zoothamnium* were removed, and again larvae showed poor movement and color. Only formalin, at 50 mg/l, gave complete control of *Zoothamnium* with no ill effects on larvae.

2461. Romeril, M.G. 1977. Heavy metal accumulation in the vicinity of a desalination plant. Marine Poll. Bull. 8:84-87.

At the Channel Isles of Jersey, England, a desalination plant operates during summer months to alleviate a water shortage problem associated with a seasonal tourist influx. Brine effluents produced by the plant contained elevated levels of Cu and Zn. Copper content of limpets, *Patella vulgata*, before the plant began operation in May was 20 mg Cu/kg dry wt, but was 282 mg/kg prior to closing in August. For the same period the copper level in algae, *Fucus serratus*, increased from 5.9 mg/kg to 204 mg/kg; *Fucus spiralis* increased from 4.1 mg/kg to 231 mg/kg. Zinc in *Patella* increased from 175 mg/kg to 255. Observed copper concentrations remained elevated during the winter, possibly due to the Cu coating retained on boulders and pebbles in the area.

2462. Ronald, K., S.V. Tessaro, J.F. Uthe, H.C. Freeman, and R. Frank. 1977. Methylmercury poisoning in the harp seal (*Pagophilus groenlandicus*). Science Total Environ. 8:1-11.

Hematological and blood chemistry values were examined in harp seals exposed to daily oral dosages of methylmercuric chloride (MMC). Two seals, exposed to 0.25 mg MMC/kg body wt/day for 60 and 90 days, respectively, did not show abnormal blood values. Two other seals exposed to 25.0 mg MMC/kg body wt/day died on day 20 and 26 of exposure with 26.8 and 30.3 mg Hg/1 in blood, respectively. Blood parameters indicated toxic hepatitis, uremia and renal failure. Total mercury and methylmercury values in tissues of harp seals fed mercury suggested that this species tolerates high levels of mercury in brain and that observed renal and hepatic dysfunctions were related to high accumulations of mercury in these tissues. Total mercury levels (mg/kg wet wt) in tissues of seals exposed to 0.25 mg/kg/day of MMC for 90 days were: 82.5 in liver; 50.6 in kidney; 42.7 in muscle; 21.8 in brain; 17.1 in small intestine; 20.0 in spleen; 15.9 in heart; 18.2 in lung; 25.0 in adrenal; 13.1 in blood; 1.6 in hair; 22.3 in claws and 0.2 in blubber. Tests of renal function were useful in cases of severe methylmercury poisoning.

2463. Rosenberg, R. 1977. Effects of dredging operations on estuarine benthic macrofauna. Marine Poll. Bull. 8:102-104.

Dredging operations in a Swedish estuary reduced the number and diversity of benthic species. Larval recruitment in the vicinity of the dredged area was strongly affected. Concentrations of mercury and cadmium increased at one site from March to October 1974 in scallop *Pectinaria koreni* and polychaete worm *Nephtys hombergi* from 13 to 16 and 9 to 89 mg Cd/kg wet wt, respectively, and from 0.04 to about 0.15 mg Hg/kg wet wt in both species. Of polychaetes and molluscs examined, concentrations generally increased 2-3X, being higher in deposit feeders than suspension feeders. Maximum increases of 30X were recorded in *Philine* sp. and *N. hombergi*. From 1971 to 1974, maximum zinc increases were in deposit feeding molluscs *Chenopus pespelicani*, 2890 mg Zn/kg, and *Abra alba*, 1110 mg/kg. Copper increased at one station to 150 mg/kg in *N. hombergi* and to 260 mg/kg in *A. alba*, but no increase was found at other stations. Values of lead were >100 mg/kg in 3 species in 1974. Nickel concentrations increased 70X at several stations; 9 species, particularly carnivores and deposit feeders, contained >100 mg/kg. One and a half years later, after dredging was stopped, concentrations of metals in benthic fauna studied had decreased. Reductions of Hg in filter feeders *Mytilus edulis* and *Ostrea edulis* were 16-52%, while in *N. hombergi*, a carnivore and deposit feeder, it was

>55%. Zn in oysters decreased 37-69% and in N. hombergi 95-98%.

2464. Ryndina, D.D. and L.I. Rozhanskaya. 1976. The role of polysaccharides of the brown algae Cystoseira barbata in the extraction of Mn from seawater. Soviet Jour. Mar. Biology 1(3):221-224.

Accumulation of manganese from seawater by living, dead and decomposing thallomes of C. barbata under normal conditions and under an oxygen deficiency, as well as by individual polysaccharides (alginic acids and algulose) isolated from these algae, was determined. Carbohydrate composition of dead algae had no significant influence on absorption of Mn-54. A lowering of oxygen tension from the control value of 6 mg/l to 2.3-3.0 mg/l lowered absorption capacity of C. barbata for Mn-54 by 7.4 fold for Mn^{2+} and 9.8 fold for Mn^{4+}. Concentration function of alginic acids and algulose of detritus origin increased by 3.9 and 12.7 fold, respectively. This is associated with a change in pH of the medium. Polysaccharides from freshly collected samples of algae absorbed substantial amounts of Mn-54. Barium fucoidan, possibly formed in Cystoseira intracellular fluid concentrated Mn-54, but a lowering of oxygen tension reduced accumulation rate.

2465. Saliba, L.J. and M.G. Vella. 1977. Effects of mercury on the behavior and oxygen consumption of Monodonta articulata. Marine Biology 43:277-282.

The trochid snail M. articulata was exposed to mercuric sulphate at concentrations of 0.2, 0.5, 0.8 and 1 mg/l Hg^{2+}. At 24 hrs, retraction into the shell was observed in 0.8 and 1 mg/l Hg^{2+}. Retracted snails died if held in the solutions, but generally recovered within 24 to 48 hrs if transferred to uncontaminated seawater. Immersion-emersion behavior and interface activity were studied over 24 hr by means of an aktograph. Snails in normal seawater spent more time below than above the water surface, and exhibited frequent periods of activity. Exposure to mercuric sulphate at concentrations of 0.25, 0.5, 0.8 and 1 mg/l Hg^{2+} progressively reduced both the length and frequency of activity periods. From 0.5 mg/l Hg^{2+} upwards, emersion periods increased, and immersion periods decreased. Oxygen consumption of snails was measured in seawater and in mercuric sulphate at concentrations of 0.2, 0.5, 0.8 and 1 mg/l Hg^{2+}. Values in ul/g/hr were 257 (controls), 91 (0.2), 78

(0.5), 66 (0.8) and 59 (1.0 mg Hg/1). It is postulated that mercury affects *M. articulata* by interfering with respiration, initially reducing interface activity, then forcing the snail out of the water for longer and longer periods. Retraction occurs when activity is no longer possible. It is concluded that respiratory and behavioral alterations of this nature would afford a good indicator of the presence of sublethal concentrations of pollutants.

2466. Sandhu, S.S. 1977. Study on the post-mortem identification of pollutants in the fish killed by water pollution: detection of arsenic. Bull. Environ. Contamin. Toxicol. 17:373-378.

Herbicidal (arsenical) aerial spraying of a cotton field in South Carolina produced contamination of an adjoining reservoir, with resultant fish kill. Three dead catfish, *Ictalurus punctuaus*, each about 400 gms, collected 30 hours after spraying, contained 5.1 mg arsenic/kg in muscle. Water concentration in the pond was 2.5 mg As/l. Collections 7 weeks later showed 12.4 mg As/kg in catfish and 1.9 mg As/l in water, suggesting that As bioaccumulation continued in surviving fish though water levels decreased. The fall in As water content may have been due to flushing by heavy rains between sampling times, as well as by absorption by bottom sediments.

2467. Sarsfield, L.J. and K.H. Mancy. 1977. The properties of cadmium complexes and their effect on toxicity to a biological system. *In*: Drucker, H. and R.E. Wildung (eds.). Biological implications of metals in the environment. ERDA Symp. Ser. 42:335-345. Avail. as CONF-750929 from Nat. Tech. Inf. Serv., U.S. Dept. Comm., Springfield, VA 22161.

Relative toxic strength of cadmium ions is a function of their complex forms within cells. Intracellular Cd concentrations which inhibited photosynthetic oxygen production 50%, $(ID_{50})_i$, in algal cells of *Chlorella pyrenoides*, exposed to cadmium-ligand solutions not exceeding 0.112 mg Cd/l, for 8 days, were 146 x 10^{15} mg/cell for uncomplexed Cd, 220 x 10^{15} mg/cell for phthalate, 253 x 10^{15} mg/cell for citrate, and 373 x 10^{15} mg/cell for ethylenediamine diacetic acid in one strain. A second algal strain had $(ID_{50})_i$ values of 124 x 10^{15} mg/cell for uncomplexed Cd, 217 x 10^{15} mg/cell for ethylenediamine diacetic acid, and 270 x 10^{15} mg/cell for quinolate. Stability constants (Ks) of complexes were directly correlated to these toxicity results.

2468. Sartory, D.P. and B.J. Lloyd. 1976. The toxic effects of selected heavy metals on unadapted populations of *Vorticella convallaria var similis*. Water Research *10:1123-1127*.

The presence of large amounts of heavy metals in sewages may cause severe disruption of the biological processes involved in sewage treatment, and thus a decline in quality of the effluent produced. Unadapted populations of a sessile peritrich protozoan abundant in healthy rivers, activated sludge, percolating filters and slow sand filters were subjected to a range of 0.0001-100.0 mg/l of Pb, Hg or Zn. *Vorticella* were killed by concentrations of 0.0005 mg/l and higher of lead or mercury. Colonies were also killed by concentrations ≤ 0.075 mg/l of Zn. LC-50 (12 hr) values were 0.0036 mg Pb/l, 0.005 mg Hg/l, and 0.29 mg Zn/l.

2469. Say, P.J., B.M. Diaz, and B.A. Whitton. 1977. Influence of zinc on lotic plants. I. Tolerance of *Hormidium* species to zinc. Freshwater Biology 7:357-376.

Field studies from sites in Europe polluted by past or present mining activities, supplemented by laboratory studies, were conducted on zinc tolerance of the algae *H. rivulare*, *H. flaccidum*, and *H. fluitans*. Maximum mean metal levels in mg/l from these sites were 22.8 for Zn, 0.37 for Cu, 0.97 for Pb, 0.88 for Cd, 585.2 for Mg, and 211.5 for Ca. *H. rivulare* and *H. flaccidum* were found at the site with the highest zinc level. Tolerance index concentrations of Zn for *H. rivulare* ranged from 1.2 to 17.0 mg/l, for *H. flaccidum* 1.0 to 13.5 and for *H. fluitans* 1.6 to 2.7; populations from sites with higher Zn levels showed increased resistance to zinc. Cadmium and lead appear to increase the toxicity of zinc to these filamentous green algae; magnesium, calcium, and various hardness factors decrease zinc toxicity. An increase in PO_4-P and decrease in pH may also reduce Zn toxicity, at least in *H. rivulare*.

2470. Say, P.J. and B.A. Whitton. 1977. Influence of zinc on lotic plants. II. Environmental effects on toxicity of zinc to *Hormidium rivulare*. Freshwater Biology 7:377-384.

Tolerance index concentrations (T.I.C.) for a zinc-sensitive algal population of H. rivulare ranged from 0.54 to 1.65 mg/l for Zn, and 0.04 for Cd; T.I.C. for a zinc-tolerant population were 5.2 to 16.8 for Zn and 0.34 for Cd. Cadmium alone was 34X more toxic than zinc to a Zn + Cd sensitive population, and 15.5X more toxic to a Zn + Cd tolerant one. Toxic effects of zinc and cadmium were synergistic at levels $\geq$ 0.01 mg Cd/l. Toxicity of zinc was decreased by rises in magnesium, calcium, and phosphate levels, and increased by rises in pH. Sodium, chloride, and sulphate had no detectable influence on zinc toxicity. When applied at 50 mg/l or higher, Ca was always more effective than Mg at reducing Zn toxicity, raising the T.I.C. to about 40 mg Zn/l. The reverse was sometimes true at lower concentrations. Calcium had a proportionately greater effect in decreasing Cd toxicity, which was highly toxic, than Zn toxicity. Both Mg and PO_4-P were more effective with Zn-tolerant than Zn-sensitive populations.

2471. Schmidt-Nielsen, B., J. Sheline, D.S. Miller, and M. Deldonno. 1977. Effect of methylmercury upon osmoregulation, cellular volume, and ion regulation in winter flounder, Pseudopleuronectes americanus. In: Vernberg, F.J., A. Calabrese, F.P. Thurberg, and W.B. Vernberg (eds.). Physiological responses of marine biota to pollutants. Academic Press, N.Y.:105-117.

Winter flounder in seawater were given methylmercury injections daily or every other day corresponding to 1 mg Hg/kg wet wt for each fish. Accumulation of Hg, in mg/kg wet wt per dosage, were 0.11 for muscle, 0.92 for intestine, and 2.0 for liver. With a total dose of 13 mg Hg/kg, Hg levels rose steadily to 2.0 in muscle, 10.0 in intestine, and 22.0 in liver. Only one fish survived the 13 mg Hg/kg total dosage. Between 2 and 13 mg Hg/kg total dose, Hg ranged from 3 to 9 mg/kg wet wt in red cells, 7 to 14 in kidney, and 13 to 25 in gill. Control had $<$ 1 mg Hg/kg in muscle, intestine, liver, and kidney, and $<$3 in red cells and gill. As Hg concentration increased to 24 mg/kg wet wt, no significant change in intracellular concentrations of K, Cl, Ca, or Mg occurred in all tissues tested; water content of cells was not affected; and plasma osmolarity decreased slightly. Na^+, K^+-ATPase activity was higher in bladder and kidney of Hg-treated fish than controls, but no differences were evident in gill or intestine.

2472. Scott, J.S. 1977. Back-calculated fish lengths and Hg and Zn levels from recent and 100-yr-old cleithrum bones from Atlantic cod (Gadus morhua). Jour. Fish. Res. Bd. Canada 34:147-150.

Dimensions of cleithrum bones from fresh Atlantic cod were measured and plotted against observed fish lengths to back-calculate cod lengths from cleithra collected in 1864. Mean mercury concentration in 100 year old bones was 55.6 ug/kg dry wt and 69.0 ug/kg in recent cod. Neither showed an increase in Hg with fish length as well. Overall zinc levels appear to have increased since 1865, with Zn showing increases with fish length as well. Average concentration of Zn in recent cod was 53.5 ug/kg and 45.1 ug/kg in 100-yr-old cod.

2473. Seeliger, U. and P. Edwards. 1977. Correlation coefficients and concentration factors of copper and lead in seawater and benthic algae. Marine Poll. Bull. 8:16-19.

As total copper in seawater from Raritan Bay, near metropolitan New York, rose from 0.002 to 0.022 mg/l, Cu in seaweeds increased linearly from approximately 2 to 160 mg/kg dry wt in Blidingia minima, from 17 to 77 mg/kg in Entermorpha linza, 14 to 38 mg/kg in Ulva sp., and 8 to 48 in Fucus vesiculosus. Most of the copper was in suspended rather than dissolved form. As total lead in the same water rose from 0.002 to 0.010 mg/l, Pb in seaweeds also increased linearly, from about 12 to 172 mg/kg dry wt in Blidingia, from 18 to 68 mg/kg in Enteromorpha, 20 to 76 mg/kg in Ulva, and 8 to 38 mg/kg in Fucus. Suspended lead made up almost 80% of total Pb found in algae and water. Metal levels generally decreased as distance from the inlets of Raritan Bay increased. Concentration factors of Cu in algae (mg/kg dry wt) over seawater (mg/l) were 7100-18,300 for Blidingia, 5600-7700 for Enteromorpha, 4700-8600 for Ulva, and 3600-7400 for Fucus. CF's of lead were 27,000-82,000, 20,000-45,000,17,000-49,000, and 13,000-24,000 for the respective algal species. CF's of Cu and Pb for Blidingia are among the highest reported to date.

2474. Sheline, J. and B. Schmidt-Nielsen. 1977. Methylmercury-selenium: interaction in the killifish, Fundulus heteroclitus. In: Vernberg, F.J., A. Calabrese, F.P. Thurberg, and W.B. Vernberg (eds.). Physiological responses of marine biota to pollutants. Academic Press, N.Y.:119-130.

Interaction of selenium and mercury in killifish was studied in groups injected with the following: 1.0 mg Hg/kg body wt Hg-203 methylmercury, with or without previous injection of 0.4 mg Se/kg body wt 30 mins. before Hg addition; 1.0 Hg/kg of C-14 methylmercury, with or without 0.4 mg Se/kg pretreatment. Se pretreatment had no effect on Hg retention from Hg-203 or C-14 labelled doses in whole body of fish. After 5 hrs, Hg levels in all groups were 0.99 to 1.09 mg/kg; after 25 hrs, levels were 0.86 to 1.03. Hg distribution 3 hrs after methylmercury injection showed lower kidney/gill ratios with Se pretreatment, significantly lower red cell/gill ratios, higher liver/gill ratios, and significantly higher muscle/gill ratios. At 5, 25, and 73 hrs after injections, kidney/gill Hg-203 ratios of Se pretreated fish were half that for fish with no Se. Kidney concentrations were 1.3 and 1.6 mg Hg/kg with only Hg, and 0.7 with Hg and Se after 73 hrs. Liver/gill Hg-203 ratios were slightly lower with Se pretreatment, but not significantly. Hg in liver at 73 hrs was 1.6 to 2.0 mg/kg with only Hg, and 1.1 with Hg and Se. Distribution of C-14 and Hg-203 in various tissues was identical under all conditions; indicating that Se caused little or no increased breakage of C-Hg bonds in methylmercury. Authors concluded that all findings in Fundulus were similar to those reported for mammalian tissues, viz, pretreatment with selenite causes no changes in overall body retention of Hg, a marked redistribution of Hg among organs, and no measureable increase in C-Hg bond cleavage in methylmercury.

2475. Sheppard, C.R.C. 1977. Relationships between heavy metals and major cations along pollution gradients. Marine Poll. Bull. 8:163-164.

Along some pollution gradients in the Mediterranean, animal tissue concentrations of several physiologically important cations vary greatly, up to 4X, corresponding to levels of toxic metals, which may be the underlying cause of stress. In the presence of Pb, Cu, Ni, or Zn, calcium levels increased significantly in urchins Paracentrotus and Arbacia and in the limpet Patella. Magnesium levels also increased slightly, while potassium decreased in these invertebrates; sodium decreased in urchins but increased in Patella. Mean values of Ca ranged from 3900-6200 mg/kg wet wt in animals from least polluted waters and 9400-22,300 from the most polluted waters; Mg was 620-2100 and 2600-4900 mg/kg wet wt, respectively; K range was 4300-10,100 and 1200-1700, respectively. Na was 9200-12,100 in least polluted gradients and 4300-4700 in most polluted in urchins, while 2800 in least polluted and 15,100 in most polluted in Patella.

Seawater values from central Mediterranean were 480 mg Cd/1, 1490 Mg, 410 K, and 12,100 Na.

2476. Sheppard, J.C., and W.H. Funk. 1975. Trees as environmental sensors monitoring long-term heavy metal contamination of Spokane River, Idaho. Environmental Sci. Tech. 9:638-643.

Ponderosa pine trees growing on the bank of the Spokane River, Idaho, were used to monitor the River's past concentrations of Hg, Cr, Ag, Rb, Zn, Co, and Fe. Sections of cores and tree rings were analyzed by neutron activation to determine the trees' metal content as a function of tree ring age. Results indicate that these are in rough agreement with sediment core data for Coeur d'Alene Lake and the volume of ore mined in the Coeur d'Alene mining district provided that allowances are made for metal holdup in Coeur d'Alene Lake. Mean concentration ranges of various elements in mg/kg dry wood were 0.005-0.022 Hg, 0.09-0.90 for Cr, $<$ 0.02-0.18 for Ag, 0.06-0.92 for Rb, 37.7 to 109.3 for Zn, 0.019 to 0.065 for Co, 7.0 to 52.2 for Fe, 31.3 to 143.0 for Na, 631.0 to 3034.0 for K, 0.97 to 1.63 for Mn, 0.0015 to 0.0082 for La, 0.0024 to 0.0110 for Sb, and 0.0010 to 0.0035 for Au.

2477. Sherwood, M.J. and A.J. Mearns. 1977. Enviromental significance of fin erosion in southern California demersal fishes. In: Kraybill, H.F., C.J. Dawe, J.C. Harshbarber, and R.G. Tardiff (eds.). Aquatic pollutants and biologic effects with emphasis on neoplasia. Annals N.Y. Acad. Sciences 298:177-189.

Dover sole, Microstomus pacificus, was the most heavily affected teleost with eroded fins along the southern California coast. Incidence of fin erosion was highest on Palos Verdes shelf, site of a major municipal waste water discharge. Levels of trace metals, in mg/kg dry wt, in muscle of M. pacificus from this area were 0.5-3.2 for copper, 15-26 for zinc, $<$ 3.0 for cadmium, $<$ 0.2 for chromium, and $<$ 1.0 for lead. There were no significant differences in elemental composition between apparently healthy fish and those with moderate to severe fin erosion. Sole exposed to shelf sediments in the laboratory had higher concentrations of Cd in muscle and liver, Cu in liver, Pb in muscle and liver, and Zn in muscle than fish kept with silica sand. Specimens in silica sand were higher in Cr in muscle and liver, and Zn in muscle. Both groups had equal levels of Cu in muscle. Authors state that these levels were probably not associated with fin erosion. Diseased sole when compared to unaffected specimens had higher concentrations of total DDT, a tendency towards higher levels of total polychlorinated biphenyls in muscle, and a greater liver to body weight ratio. Laboratory exposure to chlorinated hydrocarbons resulted in development of fin erosion.

2478. Shore, R., G. Carney, and T. Stygall. 1975. Cadmium levels and carbohydrate metabolism in limpets. Marine Poll. Bull. 6:187-189.

Glucose levels and carbohydrate metabolism were investigated in *Patella vulgata* from several sites with varying degrees of cadmium contamination in the Bristol Channel, England, from September 1974 to May 1975. Generally, as Cd levels in digestive glands increased from 27 to 537 mg/kg dry wt, glycolytic rate decreased from 0.45 to 0.25 umol lactate/mg protein/hr, and amount of haemolymph glucose increased from 5.1 to 8.6 mg%. Maximum glycolytic rate of 0.48 umole lactate/mg protein/hr and minimum haemolymph glucose levels of 4.3 mg% were found in limpets containing 116 mg Cd/kg dry wt. Results tentatively suggest a correlation between cadmium concentrations and reduced ability to utilize glucose.

2479. Shumway, S.E. 1977. Effect of salinity fluctuation on the osmotic pressure and Na^+, Ca^{2+} and Mg^{2+} ion concentrations in the hemolymph of bivalve molluscs. Marine Biology 41:153-177.

Chlamys opercularis, *Modiolus modiolus*, *Mytilus edulis*, *Crassostrea gigas*, *Scrobicularia plana*, and *Mya arenaria*, all osmoconformers, were exposed to gradual and abrupt salinity fluctuations. In both regimes fluctuating between 100% (32 o/oo S) and 50% seawater, hemolymph concentrations of Mg^{2+} fluctuated between 55 mM and 35 to 25 mM, respectively, in *C. opercularis*. Hemolymph Na^+, Ca^{2+}, and osmotic concentrations also followed external ion concentrations. Ionic and osmotic concentrations of hemolymph and mantle fluid followed the external concentrations in *M. modiolus*, *M. edulis*, *C. gigas*, and *S. plana* only while shell valves remained open. Wedged-open *M. edulis*, supplied with a constant supply of 10 mM Ca^{2+}, showed greater changes in hemolymph concentrations due to fluctuating salinity than specimens without Ca^+ supply. *C. opercularis* and *M. modiolus* survived in 50% seawater minimum gradual fluctuations for 10 days; wedged-open M. modiolus survived only 3 days. Burrowing had no effect on hemolymph concentrations in M. arenaria or S. plana in fluctuating salinity.

2480. Shumway, S.E. and J. Davenport. 1977. Some aspects of the physiology of Arenicola marina (Polychaeta) exposed to fluctuating salinities. Jour. Marine Biol. Assn. U.K. 57:907-924.

When confronted with abrupt dilution to 30% SW of the water above their burrows, Arenicola became inactive and compressed themselves at the bottom of the burrow; they "sampled" overlying water about once every hour. Normal activity was resumed when salinity returned to the initial value of 32 o/oo. In sinusoidal salinity regimes fluctuating between 100% and 30% SW, activity stopped at 55% SW external concentration. Animals held in glass tubes rather than sand burrows ceased activity at about 70% SW, suggesting that Arenicola derives a proportion of its water for irrigation from interstitial rather than surface water. The combination of behavioral response and exploitation of interstitial water was extremely effective in maintaining coelomic fluid and tissue osmotic and ionic concentrations at a constant level. In contrast, non-burrowed worms exhibited fluctuating levels of Na, K, Ca, Mg, SO_4, and ninhydrin-positive substances with salinity changes, as expected from a highly permeable osmoconformer.

2481. Sidwell, V.D., D.H. Buzzell, P.R. Foncannon, and A.L. Smith. 1977. Composition of the edible portion of raw (fresh or frozen) crustaceans, finfish, and mollusks. II. macroelements: sodium, potassium, chlorine, calcium, phosphorus, and magnesium. U.S. Dept. Commerce, Marine Fisheries Review 39:1-11.

Na, K, Ca, P, Cl, and Mg body levels reported in the literature for about 160 species of fresh or frozen marine and freshwater crustaceans, echinoderms, elasmobranchs, fish, molluscs, and mammals are summarized. Sodium concentration ranges were 450-2760 mg/kg in crustaceans, 700-1790 in elasmobranchs, 240-3970 in fishes, 110-6180 in molluscs, and 98-242 in mammals. Potassium levels were 550-5000 mg/kg in crustaceans, 1140-5490 in elasmobranchs, 250-7120 in fishes, 35-570 in molluscs, and 3600-3700 in mammals. The range of calcium was 160-5500 mg/kg in crustaceans, 40-1640 in elasmobranchs, 50-7500 in fishes, 100-2170 in molluscs, and 15 in mammals. Magnesium concentrations ranged 120-1300 mg/kg in crustaceans, 100-440 in elasmobranchs, 100-2020 in fishes, and 120-2300 in molluscs.

2482. Sigmon, C.F., H.J. Kania, and R.J. Beyers. 1977. Reductions in biomass and diversity resulting from exposure to mercury in artificial streams. Jour. Fish. Res. Bd. Canada 34:493-500.

Mercury levels of 0.0001 and 0.0010 mg Hg/l, as $HgCl_2$, caused significant reductions in freshwater algal numbers, standing stock, and diversity over 12 months in artificial streams in South Carolina. Periphyton Hg concentrations ranged from 10 to 50 mg/kg dry wt in 0.0001 mg Hg/l and from 150 to $>$3000 mg/kg dry wt in 0.001 mg Hg/l; controls contained $<$20 mg/kg dry wt over this period. Concentration factor from water to periphyton was about 10^6 for both treatments. Reductions in diversity resulted from a decrease in evenness of distribution of numbers among species and a slight decline in number of species. Decline in algal standing crop could indirectly affect other food chain members that are Hg resistant. No direct or indirect impact on herbivorous or carnivorous midges was seen, however, since the impact on primary producers was not sufficient to be transferred to consumer trophic levels.

2483. Singleton, F.L. and R.K. Guthrie. 1977. Aquatic bacterial populations and heavy metals—I. composition of aquatic bacteria in the presence of copper and mercury salts. Water Research 11:639-642.

Effects of addition of copper as $CuSO_4$ and mercury as $HgCl_2$ was studied in bacteria populations including Pseudomonas sp., Flavobacterium sp., Brevibacterium sp., Enterobacter sp., Achromobacter sp., Escherichia sp., Sarcina sp., Caulobacter sp., Proteus sp., Micrococcus sp., Streptomyces sp., and Bacillus sp. from fresh and brackish waters. Treatment of bacterial populations with 2.0 mg/l copper or 0.04 mg/l mercury for 14 days caused an increase in total colony forming units (TCFU), a reduction in diversity, and a varied percentage of chromagens in the population. Similar results were observed when Cu and Hg were added simultaneously to a single system. The largest reduction in chromagenic percentage in Hg treated brackish water colonies occurred at days 9-10, coinciding with greatest increase in TCFU. Examination of the present genera confirmed that Flavobacterium sp. and Brevibacterium sp. were absent at the end of the 14 day test. Other organisms lost or reduced in metal treated systems included Sarcina sp., Enterobacter sp., Achromobacter sp., and Escherichia sp. Results indicate that heavy metal addition reduced bacterial community stability by reduction in diversity coincident with increased TCFU of surviving organisms.

2484. Skipnes, O., T. Roald, and A. Haug. 1975. Uptake of zinc and strontium by brown algae. Physiol. Plant 34:314-320.

Accumulation of Sr-85 by tips of Ascophyllum nodosum was reversible, and similar in living and killed plants. In 12 mg Sr/l seawater (32.7 o/oo), equilibrium of Sr exchange was reached in 1 day, at 200 mg/kg wet wt algae. Accumulation seemed to be an ion-exchange process involving negatively charged intracellular polysaccharides, mainly arginate. Only a small fraction of Zn uptake in living algae seemed to be due to a similar ion exchange with intracellular polysaccharides. Zinc uptake was a slow, irreversible accumulation of 5.5 mg/kg wet wt algae in 4 days in 0.1 mg Zn/l as $ZnCl_2$, and of 27.0 mg/kg wet wt algae by 7 days in 0.3 mg/l. Rate of Zn uptake was 0.8 mg/kg wet wt algae/day in 0.1 mg Zn/l and rose to 1.3 and 1.4 in 0.3 and 1.0 mg/l. In dead algae, uptake was reversible and rapid, 95 mg/kg wet wt algae by 7.5 days in 0.1 mg Zn/l seawater. Authors suggest that algae contain Zn-binding substances, but these were not directly accessible to Zn ions in seawater prior to death. Transfer of Zn from reversible intercellular sites to irreversible cellular sites continued undisturbed during low tide periods. Intercellular charged polysaccharides thus function as ion buffers, allowing ion uptake into the cell at a constant rate, independent of tidal movements.

2485. Smith, R.I. 1976. Exchanges of sodium and chloride at low salinities by Nereis diversicolor (Annelida, Polychaeta). Biol. Bull. 151:587-600.

The Na-uptake mechanisms in this marine polychaete reach half the maximal uptake rate at an external Na concentration of 184-230 mg/l (2% SW) and becomes "saturated" or reaches a plateau of uptake at 920-1380 mg Na/l (10% SW) up to 8050 mg/l (75% SW); above this, Na-exchange is proportional to external concentration. The Cl-uptake curve shows a relative depression at very low salinities before reaching "saturation" at

Cl concentrations of 1770-2124 (10% SW). Cl-uptake becomes proportional to external concentrations of 50% SW or greater, suggesting passive diffusion in the ionic and osmotic conforming range. Body wall permeability to both Na and Cl is reduced at very low salinities. Author suggests that the inside negative body wall potential is related to the depression of the Cl-uptake curve in salinities below 10% SW. Activation of Na-uptake at low salinities was not conclusively demonstrated because of the body wall permeability reduction.

2486. Somer, E. 1977. Heavy metals in the Baltic. International Council for the Exploration of the Sea. Fisheries Improvement Committee. C.M. 1977/E:9. 37 pp.

Baltic Sea sources, transport processes, uptake in organisms, and recommended monitoring procedures of As, Cd, Cr, Cu, Hg, Mo, Ni, Pb, and Zn are presented. Mercury concentrations in biota near discharge areas exceeded administrative limits and accumulated up the food chain to sea birds and sea mammals. Copper concentrations were generally higher in the open sea and are detected only near discharge areas along the coast. Elevated zinc levels were found only close to discharges, with moderately toxic effects. Lead, in spite of high input, and cadmium, in the Baltic have little effect on biota or man. The role of molybdenum should be investigated as a limiting factor for primary production and nitrogen fixation in blue-green algae. Recommended monitoring organisms and tissues for Hg is flounder muscle; for Cd and As it is flounder liver; for Pb, Zn, and Ni it is whole mussel; for Cu whole mussel and flounder liver; and for Cr sediment and polychaetes.

2487. Sonntag, N.C. and W. Greve. 1977. Investigation of the impact of mercury on enclosed water columns using a zooplankton simulation model. Jour. Fish. Res. Bd. Canada 34:2295-2307.

A computer simulation model of a phytoplankton-zooplankton-salmon system was used to investigate possible causes of different population dynamics of the copepod, Pseudocalanus minutus, in 0.001 and 0.005 mg/l mercury over 70 days. Diatoms and flagellates, copepods, and fingerling chum salmon, Oncorhynchus keta, were represented in the model. In general, simulated and observed growth of all organisms in 0.001 mg Hg/l was equal to or better than controls; in 0.005 mg Hg/l little growth was seen. The model supported the hypothesis that observed reduction in *Pseudocalanus* populations after day 25 could have been a direct consequence of different flagellate populations in the system rather than lethal effects of Hg on molting and reproduction success of copepods.

2488. Stevens, D.G. 1977. Survival and immune response of coho salmon exposed to copper. U.S. Environ. Protect. Agen. Rept. EPA-600/3-77-031: 36 pp.

Juvenile coho salmon, *Oncorhynchus kisutch*, were vaccinated with bacteria *Vibrio anguillarum*, by oral administration during copper exposure and intraperitoneal injection prior to exposure in order to investigate effects of Cu upon survival and immune response to vibriosis. Measured Cu concentrations of 0.018 to 0.034 mg/l caused 35 to 100% mortality among coho fry over 30 days. Survivors from ≥0.014 mg Cu/l exposed to *V. anguillarum* in seawater had at least 60% mortality after 24 days. The reduced number of dead fish positive for *V. anguillarum* suggests that sublethal Cu stress and difficulty with seawater adaptation caused several deaths. Mortality of 17 to 69% among coho fingerlings exposed to at least 0.025 mg Cu/l occurred over 31 days. Most survivors were unable to adapt to seawater and died within 3 days of *V. anguillarum* challenge. Eighteen percent mortality occurred during seawater adaption in survivors from 0.018 mg/l, whereas only 2% died during 31 days of Cu exposure. Antibody level against *V. anguillarum*, measured by agglutinin titer, was significantly reduced in fish exposed to 0.018 mg Cu/l compared to controls.

2489. Stewart, J.G. 1977. Effects of lead on the growth of four species of red algae. Phycologica 16:31-36.

Three species of marine red algae, *Platythamnion pectinatum*, *P. decumbens*, and *Pleonosporium squarrulosum* were grown in media containing up to 10 mg Pb/l. No effects of added lead on morphology or development of reproductive structures were observed, although algae grew more slowly in media containing lead. Growth of cells of *Tiffaniella snyderae* over 15 days was reduced in 0.5-10.0 mg Pb/l during days 4-8; divison rate of apical cell was not different than controls. Growth of filaments and cell division rate of this species over 28 days were both reduced in 0.5-10.0 mg Pb/l, but not 0.1 mg/l.

2490. Stickel, L.F., W.H. Stickel, M.A.R. McLane, and M. Bruns. 1977. Prolonged retention of methyl mercury by mallard drakes. Bull. Environ. Contamin. Toxicol. 18:393-400.

Retention of mercury residues by mallard ducks, Anas platyrhynchos, during 16 wks was reported following dietary exposure to 8 mg Hg/kg as methylmercury dicyandiamide for 2 wks. Whole body concentration rose to 9.1 mg Hg/kg wet wt from < 0.5, after dietary dosages, then dropped to 6.8 at 1 wk, 4.4 at 12 wks, and 2.2 at 16 wks. In carcass, Hg increased to 4.5 mg/kg wet wt, from < 0.05, during feeding, then decreased to 2.6 at 4 wks, rose again to 3.4 at 8 wks, and decreased to 0.9 at 16 wks. Concentrations in liver rose to 16.5 mg Hg/kg wet wt, from 0.06 before exposure, then declined to 11.4 at 1 week, 7.0 at 12 weeks, and 4.2 at 16 weeks. Kidney Hg increased to 17.6 mg/kg wet wt from 0.07, upon dietary dosages, then decreased to 13.8 at 1 week, 9.5 at 12 wks, and 4.6 at 16 wks. Although Hg loss was slow between 1 and 8 wks, with one half of initial concentrations still retained by 12 weeks, loss resumed concurrently with new feather growth and continued through the close of the 16 week study.

2491. Stokes, P. and T.C. Hutchinson. 1976. Copper toxicity to phytoplankton, as affected by organic ligands, other cations and inherent tolerance of algae to copper. In: Andrew, R.W., P.V. Hodson, and D.E. Konasewich (eds.). Toxicity to biota of metal forms in natural water. Great Lakes Res. Advis. Bd., Standing Comm. Sci. Basis Water Quality Criteria Inter. Jt. Comm. Res. Advis. Bd.: 159-185.

Maximum metal concentrations in selected Ontario lakes near mining and smelting activities were 0.07 mg/l for Cu, 2.00 for Ni, 0.12 for Zn, 0.16 for Co, 0.33 for Mn, 0.28 for Fe, and 60.80 for Ca. High algal growth of Chlorella vulgaris correlated with low Cu and Ni levels and high Cu-complexing capacity of lake waters. Scenedesmus acuminatus was more sensitive than Chlorella which is a facultative heterotroph; its ability to use organic carbon from organic matter may have caused amelioration of metal toxicity. Growth of Scenedesmus in waters spiked with 0.2 mg Cu/l showed that tolerance of Cu was related to the waters' complexing capacity. Complexing capacity of lakes was a function of season, and amounts of organic carbon and ligands including EDTA and acetate. Copper at 0.3 and 1.0 mg/l acted synergistically with 0.0, 1.0 and 3.0 mg Ni/l on growth inhibition of *Scenedesmus*.

2492. Sturesson, U. 1976. Lead enrichment in shells of *Mytilus edulis*. Ambio 5:253-256.

Enrichment of lead in various fractions of mussel shells was studied during immersion for 35 to 150 days in seawater concentrations of 0.00, 0.02, 0.10, and 0.50 mg Pb/l. Maximum enrichment at 0.02 mg/l was 180 mg/kg in newly formed calcium carbonate. At 0.1 mg/l this was 550 in periostracum from older shell, and at 0.5 mg/l it was 4200 in older periostracum. Intermediate levels were found in new periostracum and the organic conchiolin matrix. Minimum Pb values were from older calcium carbonate, and pure carbonate from calcitic and calcitic/aragonitic regions. Lead accumulation in older periostracum increased from 550 mg/kg in 0.1 mg/l to 4200 mg/kg in 0.5 mg/l, while newly formed periostracum increased from 300 to 1500 mg/kg. Levels in newly formed carbonate fractions increased from 300 to 1100 mg Pb/kg at the same seawater concentration intervals, while older carbonate increased from 50 to 100 mg/kg. Two suggested paths for lead enrichment are passive accumulation by adsorption on surfaces in direct contact with the seawater, and active accumulation through the mantle governed by metabolic processes.

2493. Sullivan, C.W. 1976. Diatom mineralization of silicic acid. I. $Si(OH)_4$ transport characteristics in *Navicula pelliculosa*. Jour. Phycology 12:390-396.

Uptake of silicic acid by the freshwater diatom, *N. pelliculosa*, using Ge-68$(OH)_4$ as a tracer, was initially dependent on cell number, pH, temperature, and light, and was promoted by certain cations in the medium. Compared with controls, initial uptake rate was 68-97% in 32.2 mg Na/l, 49-73% in 54.7 mg K/l, and < 20% in 9.7 mg Li/l or 25.2 mg NH_4/l. Uncouplers and inhibitors of oxidative phosphorylation and of photophosphorylation reduced uptake by 40-99% of controls. Uptake was also especially sensitive to 10^{-5}M sulfhydryl blocking agents; valinomycin at 10^{-7}M inhibited uptake by 82%. The $Si(HO)_4$ transport system displayed Michaelis-Menten-type saturation kinetics. Acid-soluble silicic acid pool size suggested that intracellular levels of Si could reach 562 mg/l and as much as 480.5 mg/l free silicic acid, maintaining a 250-fold concentration gradient over the medium. Initial uptake rate of $Si(OH)_4$ in logarithmic phase cells was constant, but uptake rates increased linearly for 6 hrs in stationary phase cells. Efflux from preloaded cells was dependent on temperature and external $Si(OH)_4$ concentration. In 96,000 mg/l "cold" $Si(OH)_4$, about 30% of silicic acid in preloaded cells was exchanged in 20 min. Results suggest that the first step in silica mineralization by diatoms is active transmembrane transport of $Si(OH)_4$ by an energy dependent, saturable, membrane-carrier mechanism which requires Na^+ and K^+ and is sensitive to sulfhydryl blocking agents. Silicic acid transport activity also appears to be regulated during different growth stages of the diatom.

2494. Sullivan, J.T. and T.C. Cheng. 1976. Comparative mortality studies on *Biomphalaria glabrata* (Mollusca: Pulmonata) exposed to copper internally and externally. Jour. Invert. Pathology 28:255-257.

Higher mortality resulted in freshwater snails, *B. glabrata*, when incubated in copper concentrations than injection with Cu to attain the same concentrations in hemolymph. All snails died within 24 hrs when incubated in 500 mg Cu/l, while only 20% died when injected with this concentration. After injection of 1,000 mg Cu/l, 80% of the snails died over 24 hrs; all died with an injection of 2500 mg/l. Injection of Cu into the hemocoel of *B. glabrata* resulted in formation of a non-cellular hemolymph precipitate, most likely denatured protein, at the injection site, which was most noticeable with higher concentrations. It was concluded that external levels of Cu are more toxic to snails than internally injected concentrations, supporting the hypothesis that biocidal action of Cu is due to an attack on the snail's surface epithelia.

2495. Sutterlin, A.M., L.R. MacFarlane, and P. Harmon. 1977. Growth and salinity tolerance in hybrids within *Salmo* sp. and *Salvelinus* sp. Aquaculture 12:41-52.

Attempts were made to complete all possible interspecific hybrid crosses between Atlantic salmon *Salmo salar*, rainbow trout *S. gairdneri*, brook trout *Salvelinus fontinalis*, lake trout *S. namaycush*, and Arctic char *S. alpinus*. Survival was appreciable only in the matings (female listed first) of lake x brook, salmon x char, brook x char, and char x brook. Different species and hybrids may be divided into four groups exhibiting increasing tolerance to 39.4 o/oo sainity, at 12 C: C x C = L x L = B x B = B x C < S x B = S x S < R x R < S x C.

Salvelinus spp. and their intrageneric hybrids have less tolerance to increasing salinity than *Salmo* spp. The least tolerant group had 98% mortality in just over 10 hours, while the most tolerant (S x C) had 80% mortality by 100 hours.

2496. Suzuki, T., T. Miyama and C. Toyama. 1973. The chemical form and bodily distribution of mercury in marine fish. Bull. Environ. Contamin. Toxicol. 10:347-355.

Many types of fish, including mackerels *Auxis tapeinosoma*, *Trachurus japonicus*, and *Caranx sexfasciatus*, grouper *Epinephelus septemfasciatus*, rockfish *Sebastes inermis*, greenling *Hexagrammos otakii*, hairtail *Trichiurus lepturus*, blue runner *Caranx equula*, yellowtail *Seriola quinqueradiata*, nemipterid *Nemipterus virgatus*, catalufa *Priacanthus macrocanthus*, crimson sea bream *Evyunis japonica*, and lethrinid *Lethrinus choerorhyncus*, were collected from the South China Sea, off northwestern Australia and in the Japan Sea. All were analysed for mercury content. Mean values of total mercury in organ and gastric content of all fish in mg/kg wet wt was: 0.20 in muscle; 0.86 in liver; 0.66 in brain; 0.72 in kidney; and 0.072 in gastric content. Mean inorganic mercury levels were 0.006 muscle, 0.27 liver, 0.015 brain, 0.25 kidney, and 0.030 in gastric content. In muscle, the highest percent of inorganic mercury of the total Hg content was 17.6 in catalufa. In the brain of one hairtail, the level of total Hg was 7.36 mg/kg, all organic. In the case of inorganic mercury, 3 significant correlations were found: kidney to muscle; kidney to liver; and liver to brain. For organic mercury the significant correlations were: muscle to brain; liver to kidney; and brain to kidney. Total mercury in the gastric content correlated significantly with total Hg in liver or muscle. For inorganic Hg, gastric content correlated significantly with liver, kidney and muscle.

2497. Sylvester, A.J. and G.C. Ware. 1977. Laboratory studies on the effect of metals on oxygen uptake by sewage sludge in brackish water. Marine Poll. Bull. 8:45-48.

Cadmium, lead, and zinc industrial wastes dumped into the Bristol Channel apparently stimulates the growth of certain bacteria in water and may hasten the self-purification process. In the laboratory 100 ml of artificial seawater and a known concentration of a heavy metal was added to 100 ml of sewage sludge. Dissolved oxygen consumption was recorded as a measure of bacterial action. Cadmium, as $CdCl_2$, at 10 mg Cd/l increased rate of O_2 uptake of sludge during a period of 12 hours, 100 mg Cd/l reduced O_2 uptake rate; 1 mg Cd/l had no observable effect. A total of 200 mg/l of lead as $Pb(NO_3)_2$ stimulated O_2 uptake after 6 hrs; 20 mg Pb/l had no observable effect; 500 mg Pb/l reduced O_2 uptake rate. At 500 mg Zn/l as $ZnCl_2$, O_2 uptake rate after 48 hrs was stimulated; 50 mg Zn/l had no effect and 1000 mg Zn/l reduced O_2 uptake although it parallelled control values. This increased rate of O_2 uptake due to moderate concentrations of metals may be an example of the Arndt-Schultz effect, which describes the general tendency for poisonous substances in low concentrations to stimulate rather than depress biological processes.

2498. Tafanelli, R. and R.C. Summerfelt. 1975. Cadmium-induced histopathological changes in goldfish. In: Ribelin, W.E. and G. Migaki (eds.). Pathology of fishes. Univ. Wisconsin Press, Madison, WI:613-645.

Toxicity, body distribution, and histological damage effects of cadmium on goldfish, Carassius auratus, is presented. LD-50 in intraperitoneal injections of $CdCl_2$ was 30 mg/kg (24 hr), 23 (48 hr), and 20 (96 hr). Liver, because of its larger mass, contained the largest quantity of Cd, but kidney had the highest concentration. Concentrations were >400 mg Cd/kg dry wt in kidney, up to 300 in liver, <100 in ovary and <6.5 in muscle. Authors suggest that Cd may have serious effects on osmoregulation, hematopioesis, and gametogenesis, resulting in reduced fecundity and destruction of vital organs. Cadmium residues in flesh of fish suggests biological magnification through the food chain, with possible transfer to man.

2499. Takeuchi, T., F.M. D'Itri, P.V. Fischer, C.S. Annett, and M. Okabe. 1977. The outbreak of Minamata Disease (methyl mercury poisoning) in cats on Northwestern Ontaria reserves. Environ. Res. 13:215-228.

Pathological, histochemical, and analytical studies confirmed the presence of Minamata Disease in at least one of two cats from near Indian Reserves in Northwest Ontario, Canada, after long-term ingestion of fish from the English River. Maximum concentrations of mercury reported from other sources in freshwater fish from the Ontario waters were 19.6 mg/kg wet wt of muscle in Stizostechion vitreum, 24.8 for Lota lota, and 27.8 for Esox lucius, and these approximated levels in fish from mercury-contaminated Minamata Bay, Japan. Tissue levels of total mercury in the two cats were 16.4 and 6.9 mg/kg wet wt in brain, 4.9 and 4.3 in pancreas, 13.4 and 10.8 in kidney, 67.1 and 14.2 in liver, 17.6 in blood (one cat only), and 392 and 121 in fur. The cat with higher values, comparable with symptomatic cats in Japan, developed acute neurological symptoms including ataxic gait, uncontrolled howling, and seizures.

2500. Tarao, R., T. Tabata, and M. Yasuhara. 1976. The accumulation of mercury in the fishes reared in the sea water contaminated by suspended solids containing mercury. Bull. Japan. Soc. Sci. Fish. 42:1411-1422.

Three species of marine teleosts, bream Chrysophrys major, majina Girella punctata, and rockfish Sebasticus marmoratus were reared in seawater containing mercury-contaminated mud from Minamata Bay, Japan. One group was reared in seawater-mud suspensions containing 600 mg Hg/kg dry wt; a second group in 100 mg Hg/kg dry wt; and a control of 0.1 mg/kg. Hg in muds was present mainly as insoluble compounds. Total and methylmercury in fish flesh increased slightly over 90 days although equilibrium values were low; the maximum value recorded for total Hg was 0.28 mg/kg wet wt in majina, and for methyl Hg it was 0.14 in rockfish. Fishes reared in aerated seawater irradiated with ultraviolet light had slightly higher equilibrium values: 0.32 mg/kg for total Hg, and 0.17 for methyl Hg. As total Hg from mud suspensions varied from 600 to 0.1 mg/kg dry wt, no change in rate or extent of Hg accumulation was seen. Authors concluded that there was little possibility of mercury accumulation into fish from mud suspensions containing insoluble Hg exceeding established maximum permissible levels.

2501. Terhaar, C.J., W.S. Ewell, S.P. Dziuba, W.W. White, and P.J. Murphy. 1977. A laboratory model for evaluating the behavior of heavy metals in an aquatic environment. Water Research 11:101-110.

A dynamic biological system capable of simultaneously distinguishing between bioaccumulation and biomagnification through successive trophic levels in an aquatic ecosystem is described, using algal cultures of predominately Scenedesmus sp., Daphnia magna, freshwater mussels Ligumia sp. and Margaritifera sp., and fathead minnows Pimephales promelas. Effects of thioslufate-complexed mercury, at 0.002 and 0.005 mg/l, and silver, at 0.5 and 5.0 mg/l, were studied over 10 weeks. Maximum concentration factors in organisms exposed to 0.5 mg Ag/l were 240 for algae after 5 wks, 36 for Daphnia after 5 wks, 8.2 for mussels after 7 wks, and 28 for fish after 10 wks. CF in 5.0 mg Ag/l were lower for each organism. Biomagnification indices for fish increased to 90 in 0.005 mg Hg/l, but stayed at 0 in 5.0 mg Ag/l. Metal concentrations in control animals never exceeded 0.1 mg Hg/kg wet wt or 11.0 mg Ag/l over 10 wks. Authors concluded that both Hg and Ag were bioaccumulated in fish, with Hg greater than Ag; Hg but not Ag was biomagnified. Freshwater mussels were relatively poor indicators of metal contamination.

2502. Thomas, W.H., O. Holm-Hanse, D.L.R. Seibert, F. Azam, R. Hodson, and M. Takahashi. 1977. Effects of copper on phytoplankton standing crop and productivity: controlled ecosystem pollution experiment. Bull. Marine Science 27:34-43.

Copper concentrations of 0.01 and 0.023-0.05 mg/l added at day 2 initially inhibited phytoplankton photosynthesis and growth. Total particulate organic carbon, biomass-carbon and phytoplankton-carbon levels dropped from >1 mg C/l to 0.035-0.30 at day 5 in both concentrations. Productivity decreased from 7.0 to 0.9-0.1 mg C/m^3/hr. Crops and photosynthesis recovered, so that at the end of the 27 day experiment, values were similar to controls. Excretion of C-14 organic carbon reached 85% during the first half of the experiment in Cu treated groups before returning to control values. There were no significant differences in C:N or C:P ratios between control and test enclosures, indicating that Cu did not change gross chemical composition of the phytoplankton. In enclosures which received 0.005 and 0.01 mg Cu/l on day 8, the algal standing crop, but no photosynthesis rate, increased over control levels. Phytoplankton-C, ATP, and productivity were higher in experimental groups after 20-25 days. Authors suggest that observed lack of inhibition due to Cu may be associated with large numbers of residual Cu-resistant microflagellates and that biomass increase could be due to inhibition of zooplankton grazing.

2503. Thomas, W.H. and D.L.R. Seibert. 1977. Effects of copper on the dominance and the diversity of algae: controlled ecosystem pollution experiment. Bull. Marine Science 27:23-33.

Addition of 0.01 or 0.05 mg/l copper to experimental enclosures caused diatoms, Chaetoceros sp., in the top 10 meters to decline from 55-85% total carbon to almost zero after 21 days. These populations were replaced mainly by microflagellates. *Nitzschia delicatissima* became the dominant diatom in 0.01 mg Cu/l and *Navicula distans* in 0.05 mg/l. Taxonomic diversity declined in both control and experimental enclosures, but was much lower in Cu treated groups. Biomass diversities also decreased, but with no significant difference between groups. In a second experiment, algal populations acclimatized for 10 days received 0.005 or 0.01 mg Cu/l. Although *Chaetoceros* sp. was dominant before Cu was added, *N. delicatissima* slowly replaced *Chaetoceros* as the dominant species by day 17 and comprised 75-90% of the crop at 28 days.

2504. Thurberg, F.P., A. Calabrese, E. Gould, R.A. Greig, M.A. Dawson, and R.K. Tucker. 1977. Response of the lobster, *Homarus americanus*, to sublethal levels of cadmium and mercury. *In:* Vernberg, F.J., A. Calabrese, F.P. Thurberg, and W.B. Vernberg (eds.). Physiological responses of marine biota to pollutants. Academic Press, N.Y.: 185-197.

Oxygen consumption in lobsters increased from 710 ml O_2/hr/kg for controls to 775 after 30 days in 0.003 mg Cd/l and to 820 after 30 days in 0.006 mg Cd/l. No changes in serum osmolality were noted in lobsters exposed to test concentrations of Cd or Hg; osmolality was maintained at 40 mOsm above seawater. No significant difference in activity of heart aspartate aminotransferase was evident between control and exposed lobsters. Cd concentration in digestive gland varied only slightly after exposure to 0.0, 0.003, and 0.006 mg Cd/l: 20.3 to 23.5 mg Cd/kg wet wt after 30 days, and 12.9 to 13.9 after 60 days. Cadmium in muscle increased with increasing concentrations: 1.5 to 3.4 mg/kg wet wt after 30 days, and 1.6 to 2.6 after 60 days. Muscle concentrations were $<$ 0.12 mg Cd/kg wet wt for all 3 concentrations at 30 and at 60 days. At Hg exposures of 0.0, 0.003, and 0.006 mg/l for 30 days, Hg levels ranged from 0.12 to 15.2 mg Hg/kg wet wt in digestive glands, 0.14 to 85.3 in gills, and 0.23 to 1.0 in tail muscle; higher concentrations reflected increasing Hg exposure levels. After 60 days, gills contained 0.05 to 119.5 mg Hg/kg wet wt, increasing with increasing exposure level.

2505. Thurberg, F.P. and M.A. Dawson. 1974. Physiological response of the cunner, Tautogolabrus adspersus, to cadmium. III. changes in osmoregulation and oxygen consumption. In: U.S. Dept. Comm. NOAA Tech. Rpt. NMFS SSRF-681:11-13. Avail. from D 83, Tech. Inf. Div., Environ. Sci. Inform. Center, NOAA, Wash., D.C. 20235.

Cunners exposed to 3-24 mg/l cadmium for 96 hrs showed no change in serum osmolality from the normal value of approximately 340 mOsm determined in control fish. Serum osmolality in fish exposed to 48 mg Cd/l rose to a mean of 390 mOsm. Cadmium reduced gill tissue oxygen consumption rates at all concentrations tested. A normal rate of 0.75 ul/hr/mg was reduced to 0.51 ul/hr/mg after exposure to Cd at concentrations of 3, 6, 12, and 24 mg/l. Oxygen consumption was 0.58 ul/hr/mg after exposure to 48 mg Cd/l.

2506. Thurberg, F.P., and R.S. Collier. 1977. Respiratory response of cunners to silver. Marine Poll. Bull. 8:40-41.

Oxygen-consumption rates of the marine teleost, Tautogolabrus adspersus, were measured after exposure for 96 hours to $AgNO_3$ in seawater. Significant respiratory depression was observed at 0.12 mg Ag/l; concentrations above 0.50 mg Ag/l were lethal. No significant changes in blood serum osmolarity were observed during exposure.

2507. Timourian, H. and G. Watchmaker. 1977. Assay of sperm motility to study the effects of metal ions. In: Drucker, H. and R.E. Wildung (eds.). Biological implications of metals in the environment. ERDA Symp. Ser. 42:523-535. Avail. as CONF-750929 from Nat. Tech. Inf. Serv., U.S. Dept. Comm., Springfield, VA 22161.

Motility of sperm from sea urchin, Strongylocentrotus purpuratus, was determined during exposure to Zn, Ni, and Cu salts. Optical anisotropy of sperm permitted determination of orientation by a spectrophotometer with flow cells. Zinc concentrations of 0.006 to 0.654 mg/l, added as sperm were first released, increased sperm motility; motility decreased at these concentrations when zinc was added 50 min after sperm release. At 6.54 mg Zn/l, motility decreased regardless of time of addition. Nickel increased sperm motility at 0.006 to 0.587 mg/l as sperm were first released, and decreased motility at 5.87 to 587 mg/l. After 4.5 hrs exposure to Ni, inhibitory effects were overcome and motilty returned to normal. When added 50 min after released, 0.587 to 0.006 mg Ni/l caused only a slight change while 5.87 mg Ni/l caused a decrease. Copper concentrations of 0.006 and 0.0006 mg/l increased sperm motility and 0.064 to 6.35 mg/l caused a decrease, regardless of time of addition.

2508. Topping, G. and H.L. Windom. 1977. Biological transport of copper at Loch Ewe and Saanich Inlet: controlled ecosystem pollution experiment. Bull. Marine Science 27:135-141.

Chemical studies in experimental enclosures showed that a large percentage of added copper was lost from the water. Concentration of copper in the enclosure with 0.05 mg Cu/l as $CuSO_4$ dropped to 0.03 mg Cu/l during the first day, and gradually decreased to 40% of the nominal level after 25 days. Ambient concentration of Saanich Inlet water was 0.001 mg Cu/l. Similar trends were exhibited with initial doses of 0.010 and 0.005 mg/l added to Loch Ewe waters. Settlement material, consisting mainly of decaying phytoplankton, showed an increase in Cu after a short decline. In the enclosure with 0.050 mg/l, Cu concentration increased from 250 mg/kg dry wt to 800 in 20 days. In 0.01 mg/l, settled material increased from 300 to 470 mg Cu/kg dry wt. The quantity associated with settlement material was a small percentage of that lost from the water column. Copper lost by settlement appeared to be directly proportional to primary production level at both 0.005 and 0.01 mg/l levels. Loss was significantly correlated with carbon concentrations and to concentration of soluble Cu added. Cu:C ratios were higher in samples that consisted mainly of fecal pellets than those with mostly phytoplankton. Cu:Zn ratios in detritus increased to 1.2 in 0.05 mg Cu/l and 0.6 in 0.005 mg/l; for controls, this value was 0.2.

2509. Ueda, T., R. Nakamura, and Y. Suzuki. 1976. Comparison of ^{115m}Cd accumulation from sediments and sea water by polychaete worms. Bull. Japan. Soc. Sci. Fish. 42:299-306.

Deposit feeding worms, Nereis japonica, directly in contact with Cd-115m contaminated sediments accumulated 6X more cadmium than control worms after 8 days. Concentration factor in worms from seawater with 0.05 mCi Cd/l was 22 after 8 days, 200X the accumulation from sediments. Excretion patterns of Cd-115m in worms showed a biological half-life of 4 days in the short component; the long component had a much longer half-life. Upon addition of 0.01 mCi Cd/l to a simulated ecosystem, 75% of the activity was in seawater, 15% in sediments, and 10% in algae, Ulva pertusa. A rapid Cd decrease in seawater with an increase in sediments was seen during the first three days, while algal level remained constant. On day 13, Cd-115m distributions were 60, 32, and 8% in seawater, sediments, and algae, respectively. Activity ratios of Cd-115m were 9 for sediments and 21 for algae, similar to 27 for worms.

2510. Ueda, T., R. Nakamura, and Y. Suzuki. 1977. Comparison of influences of sediments and sea water on accumulation of radionuclides by worms. Jour. Radiation Res. 18:84-92.

Concentration factors of radionuclides from seawater, after 10-11 days exposure, in unfed polychaetes, Nereis japonica, were 6 for Co-60, 4 for Zr-95-Nb-95, 6 for Ru-106-Rh-106, and 6 for Cs-137. Similar concentration factors were found in worms fed contaminated algae. Excretion patterns show biological half lives in fed worms of 6 days for Cs-137, and 37, 32, and 35 days for Co-60, Zr-95-Nb-95, and Ru-106-Rh-106, respectively. Half lives were slightly longer in all cases for unfed worms. Transfer ratios of radionuclides from sediments to worms were 5% for Co-60, 0.9 for Zr-95-Nb-95, 0.6 for Ru-106-Rh-106, and 17.9 for Cs-137, in cpm/g in reference to initial sediment activity. Biological factors of sediments, calculated by comparing concentration factors with transfer ratios, were 120 for Co-60, 440 for Zr-95-Nb-95, 1000 for Ru-106-Rh-106, and 30 for Cs-137.

2511. Vaccaro, R.F., F. Azam, and R.E. Hodson. 1977. Response of natural marine bacterial populations to copper: controlled ecosystem pollution experiment. Bull. Marine Science 27:17-22.

Addition of $CuSO_4$, at 0.01 and 0.05 mg Cu/l to two enclosed marine ecosystems produced a 100 to 1000 fold increase in relative numbers and activity of bacterial heterotrophs. Two days after addition, glycine assimilation at 5 m depth increased by an order of magnitude over controls. Between days 8 and 16 there was a decline in heterotrophic activity, corresponding to a slight decline in controls. For the remainder of the 26 day period, assimilation was faster in the two copper treated enclosures. This acceleration appeared to follow release of available organic carbon from one or more copper-sensitive components of the original ecosystem. Ultimately, bacterial survivors, which demonstrated an increased tolerance to copper with time, provided a source of plant nutrients suitable for establishment of succeeding phytoplankton regimes.

2512. VanLoon, J.C. and R.J. Beamish. 1977. Heavy-metal contamination by atmospheric fallout of several Flin Flon area lakes and the relation to fish populations. Jour. Fish. Res. Bd. Canada 34: 899-906.

Concentrations of Zn, Cu, Ni, Pb, Fe, Cd, Ca, Mg, SO_4^{-2}, Hg and As were measured in lakes near the Flin Flon smelters. In a study of 31 lakes, 7 had Zn levels above 100 ug/l, 6 had levels between 50 and 100 ug/l, and the remainder had concentrations <50 ug/l. Hamell Lake contained an average of 300 ug Zn/l and 15 ug Cd/l. The lake supported populations of walleye, yellow perch, northern pike, lake whitefish, and white sucker; none of the fish, except perhaps yellow perch, were stunted. An examination of ovaries did not show abnormal development. Cliff Lake had an average of 85 ug Zn/l and 10 ug Cu/l. The lake contained an abundance of all the fish in Hamell Lake plus lake herring, burbot, trout perch and spottail shiners. There was no indication of abnormal growth or abnormal reproduction in any of these populations.

2513. Vattuone, G.M., K.S. Griggs, D.R. McIntyre, J.L. Littlepage and F.L. Harrison. 1976. Cadmium concentrations in rock scallops in comparison with some other species. U.S. Energy Research and Dev. Admin. UCRL 52022: 1-11. Avail. from Nat. Tech. Inform. Ser., U.S. Dept. of Comm., 5285 Port Royal Rd., Springfield, VA 22151.

Cadmium concentrations were determined in rock scallops *Hinnites multirugosus* and mussels *Mytilus californianus* collected in 1973 from the Channel Islands, Southern California Bight. Mean Cd concentrations in mg/kg wet wt were 1.8 in mussel soft tissue; 31.2 in rock scallop soft tissue; 0.3 in scallop adductor muscle; and 46.3 in scallop visceral mass. Scallop Zn and Cd mean levels in mg/kg wet wt were 37.2 and 10.1, in kidney respectively, and 68.8 and 211.0, in digestive gland plus stomach, respectively. Cadmium levels in algae Macrocystis sp, Laminaria sp. Egregia laevigata and Bossea sp., abalone Haliotes corrugata, lobster Panulirus interruptus, and sea urchin Strongylocentrotus franciscanus are also reported. Maximum Cd values were 2.7 mg/kg wet wt for algae, 82.2 for abalone digestive gland, 0.3 for abalone muscle, 29.3 for lobster hepatopancreas, 0.2 for lobster muscle and 0.6 for urchin gonad. Tracer experiments with Cd-109 confirmed that rock scallop tissues concentrated Cd to a greater degree than the corresponding tissues of the mussel. Maximum CF values recorded for Cd were 11,800 for scallop kidney, and 4500 for mussel kidney; lowest CF values were in body fluid of scallop (15) and mussel (4).

2514. Vernberg, W.B., P.J. DeCoursey, M. Kelly, and D.M. Johns. 1977. Effects of sublethal concentrations of cadmium on adult Palaemonetes pugio under static and flow-through conditions. Bull. Environ. Contamin. Toxicol. 17:16-24.

Mortality and cadmium uptake in grass shrimp increased with increasing salinity during immersion in seawater containing 0.05 mg Cd/l. Maximum mortality was in 30 o/oo S with 25% dead in 21 days. Cd concentration in shrimp held in 30 o/oo increased to 8 mg/kg dry wt at 3 days, 13 at 7 days, 29 at 14 days, and 36 mg/kg at 21 days. At 25 C for 7 days, Cd levels in P. pugio decreased as salinity increased to 30 o/oo in both static and flow-through systems. Shrimp in flow-through tests had higher Cd concentrations at lower salinities than shrimp tested under static conditions. At 15 C, Cd levels in flow-through again decreased with increasing salinity; however, levels increased with increasing salinity in static systems. In both flow-through and static systems, oxygen uptake rates at 25 C or 15 C-acclimatized shrimp in 5, 15 or 30 o/oo with 0.05 mg Cd/l were generally reduced in higher salinities, but not in a predictable manner. Because of differences between the two water systems tested, authors suggest that data from flow-through systems be used since it is more applicable to field situations. Molting frequency of shrimp in 0.05 mg Cd/l under static conditions was significantly increased in 10 and 20 o/oo but not in 5 and 30 o/oo. Authors state that P. pugio is too resistant and tolerant a species to be of value for short-term bioassay studies on Cd.

2515. Walker, G. 1977. "Copper" granules in the barnacle

Balanus balanoides. Marine Biology 39:343-349.

Barnacles from Dulas Bay, U.K., which receives high heavy metal runoff, contained two different types of granules within prosomal parenchyma cells. X-ray microprobe analysis shows one to be a "zinc" granule comprised of concentric layers and high concentrations of phosphorus and zinc. The "copper" granule is homogenous with high sulphur and copper content. While "zinc" granules are composed of inorganic phosphate, the Cu in "copper" granules is probably complexed with organic matter. Both granules were relatively insoluble. Although "zinc" and "copper" granules were present together in the prosoma, atomic absorption analyses of whole bodies (prosoma plus thorax) show that zinc content (50.3 mg/kg dry wt) is much higher than copper (3.8 mg/kg dry wt); other elements detected were magnesium at 4.9, calcium at 2.3, and iron at 0.9 mg/kg dry wt.

2516. Weigel, H.P. 1977. On the distribution of particulate metals, chlorophyll, and seston in the Baltic Sea. Marine Biology 44:217-222.

Water samples from the Baltic Sea were analyzed for Cu, Fe, Zn, Cd, Pb, chlorophyll and seston during the end of the phytoplankton spring bloom . Mean metal concentrations in surface waters of the Baltic Sea in ug/l were: 0.13 Pb, 0.07 Cu, 0.006 Cd, 5.79 Fe and 0.99 Zn. Correlations between metal concentrations and chlorophyll, seston, phytoplankton carbon and cell-count were calculated for both photic layer and deeper waters. Significant correlations were found only in the photic layer. Positive correlations were found between copper and chlorophyll; phytoplankton carbon and cell counts; cadmium and chlorophyll; Cd and phytoplankton carbon; iron and chlorophyll; iron and seston; and iron and phytoplankton carbon.

2517. Weis, J.S. 1977. Limb regeneration in fiddler crabs: species differences and effects of methylmercury. Biol. Bull. 152:263-274.

Under identical conditions, isolated specimens of the crab, Uca pugnax, found in temperate waters regenerate limbs and molt faster than U. pugilator. The tropical species U. rapax and U. speciosa also regenerate faster than U. pugilator from the same location. U. thayeri regenerate more slowly when kept in groups of their own species. U. Thayeri will not complete regeneration nor molt, U. pugilator is slightly retarded in regeneration, and U. rapax is delayed in molting. Newly regenerated limbs of all 4 species are lighter in color than old limbs, and only in U. pugilator do they not darken in a few weeks after ecdysis. When treated with 0.5 mg methylmercury/l in 9 o/oo salinity, regeneration growth was halted in U. thayeri. For U. pugilator, growth was decreased to about 0.33 of controls by 21 days. Growth was inhibited least in U. rapax with 50% of crabs reaching ecdysis in 32 days. In 0.3 mg methylmercury/l, 25% of U. rapax reached ecdysis by 21 days at 9 o/oo S, while 37.5% had molted at 36 o/oo S. Methylmercury concentrations of 0.001, 0.01 and 0.1 mg/l had no effect on growth of U. rapax, and 0.1 mg/l had none on U. thayeri or U. pugilator. Melanin was absent in regenerated limbs of all three species of Uca exposed to 0.5 mg/l methylmercury, in all U. rapax exposed to 0.3 mg/l, in 25% of U. thayeri in 0.1 mgl at 9 o/oo S and 50 to 80% at 36 o/oo S, and in 25% of U. pugilator in 0.1 mg/l at both salinities. Pigment lack was attributed to inhibition of melanin synthesis.

2518. Weis, P. and J.S. Weis. 1977. Methylmercury teratogenesis in the killifish, Fundulus heteroclitus. Teratology 16:317-326.

Abnormalities resulted from exposure for 3 days of developing eggs of seawater-adapted Fundulus heteroclitus during immersion in seawater solutions containing 0.03 or 0.04 mg/l of methylmercuric chloride. Percentage of axis formation was reduced and embryos developed cyclopia or intermediate conditions leading to cyclopia, reflecting interference with induction of the forebrain. The heart failed to differentiate properly into chambers and was a thin, feebly beating tube incapable of circulating blood. Other tissues continued developing normally; embryos showed spontaneous movement comparable to controls. Embryos with severe cardiovascular or optic defects did not hatch. Upon hatching, some fish which had previously appeared normal exhibited skeletal malformations such as vertebral bends or inability to uncurl from the chorionic position. Exposure for shorter periods of time (6, 12, or 24 hrs), or to lower concentrations (0.01 or 0.02 mg Hg/l) reduced incidence of abnormalities.

2519. Weis, J.S., and P. Weis. 1977. Effects of heavy metals on development of the killifish, Fundulus heteroclitus. Jour. Fish Biology 11:49-54.

When F. heteroclitus embryos were exposed to inorganic mercury at concentrations of 0.03 or 0.1 mg/l at the early blastula stage, the percentage of successful axis formation was reduced and a significant proportion of embryos developed cyclopia or intermediate conditions leading to cyclopia. At the late blastula stage, embryos were more resistant to mercury. Embryos which developed in concentrations of 1 and 10 mg/l of Pb were normal in appearance until hatching, at which time they exhibited spiral curvature defects. No significant effects of cadmium on killifish development at concentrations up to 10 mg Cd/l were noted.

2520. Wentsel, R., A. McIntosh, W.P. McCafferty, G. Atchison and V. Anderson. 1977. Avoidance response of midge larvae (*Chironomus tentans*) to sediments containing heavy metals. Hydrobiologia 55:171-175.

Avoidance reactions of chironomid insect larvae to contaminated sediments taken from a lake impacted with heavy metals were studied. Heavy metal levels in the test sediment ranged from background levels of 0.6 mg/kg dry wt of cadmium, 77 mg/kg of zinc and 17 mg/kg of chromium to a maximum of 1029 mg/kg of cadmium, 17,262 mg/kg of zinc and 2106 mg/kg of chromium. A linear relationship was established between cadmium and zinc levels in the sediment, and avoidance by chironomids. An approximate threshold avoidance of metals in the sediment was determined to be between 213-422 mg/kg cadmium, 4385-8330 mg/kg zinc and 799-1513 mg/kg chromium.

2521. Wharfe, J.R. and W.L.F. Van Den Broek. 1977. Heavy metals in macroinvertebrates and fish from the Lower Medway Estuary, Kent. Marine Poll. Bull. 8:31-34.

Macroinvertebrates and fish collected between April 1973 and January 1976 from 10 industrialized locations were analyzed for mercury, zinc, copper, lead and cadmium. Mean metal concentrations in mg/kg wet wt in the periwinkle, *Littorina littorea*, were Hg 0.09-0.24; Zn 15.5-24.3; Cu 23.8-36.1; Pb 0.28-3.03; and Cd 0.43-0.90. For the shore crab, *Carcinus maenas*, these were Hg 0.14-0.29; Zn 25.1-38.8; Cu 15.4-31.4; Pb 0.38-3.32; Cd 0.96-2.07. In mussel, *Mytilus edulis*, these values were Hg 0.14-0.30; Zn 29.0-41.8; Cu 1.9-2.3; Pb 0.75-2.17; Cd 0.71-1.21; in ragworm, *Nereis diversicolor*, these were Zn 22.0-37.5; Cu 1.6-5.1; Pb 0.1-4.8; Cd 0.2-0.5. For shrimp, *Crangon vulgaris*, the mean concentrations were Hg 0.17; Zn 26.4; Cu 18.5; Pb 1.22; and Cd 0.59. For eel, *Anguilla anguilla*, muscle concentrations in mg/kg wet wt were Hg 0.36-0.54; Zn 23.8-27.2; Cu 0.5-0.6; Pb 0.48-1.05; Cd 0.12-0.17. For eel liver the values were Hg 0.35-1.73; Zn 51.9-71.9; Cu 14.9-25.1; Pb 0.84-2.68; Cd 0.24-0.37. Levels in muscle tissue of whiting, Merlanguis merlangus, were Hg 0.37-0.45; Zn 9.1-9.2; Cu 0.6-0.7; Pb 0.29-0.36; Cd 0.13-0.21. In whiting liver the values were Hg 0.33; Zn 28.3; Cu 2.4; Pb 0.89; Cd 0.15. Gut wall levels in whiting were Hg 0.23: Zn 23.1; Cu 1.4; Pb 0.45; Cd 0.15. Flounder, Platichthys flesus, muscle tissue concentrations were Hg 0.10-0.64; Zn 12.3-18.2; Cu 0.3-1.3; Pb 0.28-0.39; Cd 0.06-0.07. In flounder liver these were Hg 0.08-0.24; Zn 53.8-68.9; Cu 12.9-18.3; Pb 0.94-1.38; Cd 0.18. Flounder gut wall concentrations were Hg 0.17; Zn 36.2; Cu 2.7; Pb 0.72; Cd 0.19. Ovary metal concentrations in flounder were Hg 0.12; Zn 146.8; Cu 2.4; Pb 0.12; Cd 0.08. Plaice, Pleuronectes platessa, muscle tissue metal concentrations were Hg 0.15-0.27; Zn 10.0-11.9; Cu 0.8-1.1; Pb 0.70-1.15; Cd 0.08-0.14. Plaice liver tissue levels were Zn 38.9; Cu 3.3; Pb 1.34; Cd 0.18. Gut wall values in plaice were Hg 0.07; Zn 27.5; Cu 2.4; Pb 1.33; Cd 0.22. Sandy goby, Pomatoshistus minutus, whole body metal concentrations were Hg 0.16; Zn 28.7; Cu 1.17; Pb 1.0; Cd 0.24. Sprat, Sprattus sprattus, whole body concentrations were Hg 0.16; Zn 38.5; Cu 1.1; Pb 1.03; Cd 0.29.

2522. Wolverton, B.C. and R.C. McDonald. 1975. Water hyacinths and alligator weeds for removal of silver, cobalt, and strontium from polluted waters. NASA Tech. Mem. TM-X-72727:1-12. Avail. from NASA, Nat. Space Tech. Lab., Bay St. Louis, Miss. 39520.

Effects of removal of Ag, Co, and Sr from static water systems by water hyacinths Eichhornia crassipes, and alligator weeds Alternanthera philoxerides, were investigated. These plants rapidly removed heavy metals from water by root absorption and concentration. Water hyacinths removed 0.44 mg of silver, 0.57 mg of cobalt, and 0.54 mg of strontium in an ionized form per gram of dry plant material in 24 hrs. Therefore, one hectare of water hyacinths is potentially capable of removing 263 g of silver, 340 g of cobalt, and 326 g of strontium per day. Alligator weeds removed a maximum of 0.44 mg of silver, 0.13 mg of cobalt, and 0.16 mg of strontium per gram of dry plant material per day.

2523. Wolverine, B. and R.C. McDonald. 1976. Don't waste waterweeds. New Scientist 72:318-320.

Water hyacinth, Eichhornia crasspipes, which clogs waterways, was investigated as a means of treating effluents, producing biogas and fertilizer, and feeding livestock. Composition, in % dry wt, of water hyacinth grown in sewage containing about 35 mg N/l and 10 mg P/l from South Mississippi was 2.0-3.5 for K, 1.5-2.5 for Na, 0.6-1.3 for Ca, 0.2-0.3 for Mg, 0.03-0.05 for Fe, 0.005-0.05 for Zn, and 0.005-0.008 for Mn. A 0.2 hectare canal covered with water hyacinths reduced silver in laboratory effluent from 0.99 to 0.001 mg/l; amounts of P, N, organic carbon, and total dissolved and suspended solids, and biochemical oxygen demand level were also substantially reduced compared to concentrations before addition of plants. The canal received 95,000 l of chemical and photo lab wastes each day. In static lab experiments, Eichhornia absorbed Ag, Au, Cd, Co, Hg, Pb, Ni, and Sr. Roots contained 97% of the Cd and Ni within 24 hrs, though roots constituted only 18% of total dry wt.

2524. Woolery, M.L. and R.A. Lewin. 1976. The effects of lead on algae. IV. effects of Pb on respiration and photosynthesis of Phaeodactylum tricornutum (Bacillariophyceae). Water, Air, Soil Poll. 6:25-31.

Lead inhibits respiration and photosynthesis in P. tricornutum, a marine algae. In cells treated for 24 hr with 10 mg/l of lead, as $PbCl_2$, photosynthesis was completely suppressed, and respiration was reduced 75%. A concentration of 1.0 mg Pb/l reduced photosynthesis by 25%, but respiration was virtually unaffected. The vital activities of cells treated for 48 hr or 72 hr were progressively more inhibited: levels of $PbCl_2$ as low as 0.1 mg/l reduced photosynthesis and respiration by 25 to 50%.

2525. Wright, D.A. 1977. The effect of salinity on cadmium uptake by the tissues of the shore crab Carcinus maenas. Jour. Exper. Biology 67:137-146.

Cadmium accumulation by haemolymph, gills, and carapace of C. maenas was significantly higher in dilute than in full-strength seawater. This was reflected in whole body Cd levels. No salinity effect was shown with hepatopancreas or muscle Cd concentrations. In 100% to 40% seawater, crabs in 2.3 mg Cd/l as $CdCl_2$ for 14 days showed an increase of 0.45 to 0.79 mg Cd/l in haemolymph, 11.2 to 33.7 mg Cd/kg wet wt in gills, 33.7 to 112.4 mg/kg in carapace, and 1.9 to 13.1 mg/kg in whole body, with decreasing salinity. Hepatopancreas levels ranged from 22.5 to 33.7 mg Cd/kg wet wt and muscle levels stayed < 6.0 mg/kg. Uptake in 1.1 mg Cd/l showed similar trends. Over 68 days in 2.3 mg Cd/l, Cd was steadily accumulated by the carapace, to 78.7 and 45.0 mg/kg wet wt in 50 and 100% SW, respectively. Gill Cd concentration reached a maximum in 50% SW after about 14 days, which was eventually overtaken by Cd concentrations in animals in 100% SW at 40-45 days. No salinity effect on Cd uptake in gills was seen after 48 days; animals in both salinities leveled at 33.7 mg Cd/kg wet wt. Hepatopancreas Cd also plateaued at this concentration, muscle showed almost no Cd uptake, and maximum hemolymph concentrations were 0.7 to 0.9 mg Cd/l. Salinity had no apparent effect over this period on these three tissues. Whole body Cd was 258.5 mg/kg wet wt in 50% SW and 89.9 mg/kg in 100% after 68 days. Crabs loaded with Cd for a 37-day period lost 50% of whole body Cd concentration within 11 days in clean water, from 19.1 to 10.1 mg/kg wet wt. Losses from carapace and gills accounted for much of this reduction. Calcium levels in gills of crabs exposed to Cd were 0.31 mg/kg wet wt in 100% SW and 0.24 in 50%; in muscle Ca was 0.24 and 0.13 mg/kg, respectively, and in hepatopancreas it was 6.0 and 3.9. Magnesium concentrations in the respective salinites were 0.55 and 0.35 mg/kg wet wt in gills, 0.37 and 0.25 in muscle, and 1.71 and 1.01 in hepatopancreas. No relationship was established between Cd and either Ca or Mg.

2526. Wright, D.A. 1977. The uptake of cadmium into the haemolymph of the shore crab Carcinus maenas: the relationship with copper and other divalent cations. Jour. Exper. Biology 67:147-161.

Haemolymph Cd levels of C. maenas exposed to 2.3 mg Cd/l were initially dependent upon salinity. After 14 days, Cd in haemolymph was 0.63 mg/l in 50% seawater crabs and 0.38 mg/l in 100% SW specimens. This trend, however, was not sustained over 68 days. In both field and experimental conditions, nearly all haemolymph Cd in crabs became bound to haemolymph protein within several days. Although haemolymph copper and protein concentrations are highly correlated, Cd formed a significant positive relationship with each only after 21-28 days uptake. Exposure to 2.3 mg Cd/l had no obvious effects on haemolymph protein concentrations and copper up to 0.07 mg Cu/l, which were clearly dependent on feeding status. Crab mortality was often proceded by a rise in haemolymph Cd, usually before any signs of tissue breakdown were noticed. In 100% SW with 2.3 mg Cd/l, haemolymph Ca dropped from 0.56 to 0.50 and serum Ca from 0.44 to

0.38 mg/l during Cd uptake over 68 days. Haemolymph Mg and serum Mg dropped from 0.55 to 0.48 and 0.55 to 0.54 mg/l, respectively, over this period. Ca and Mg levels in 50% SW crabs showed no distinguishable trend during Cd accumulation. It was concluded that Cd loss via urine was probably unimportant. Urine Cd concentrations of 0.03 to 0.22 mg/l often exceeded serum Cd levels with a maximum of 0.07 mg/l, indicating that cadmium may sometimes be eliminated in bound form.

2527. Wright, D.A. 1977. The effect of calcium on cadmium uptake by the shore crab _Carcinus_ _maenas_. Jour. Exper. Biology 67:163-173.

Accumulation of cadmium by _C. maenas_ was, to some extent, dependent upon calcium concentration of the external medium. This effect was apparently independent of overall salinity. Whole body Cd had a highly significant inverse relationship with external Ca concentration. This was reflected by Cd levels in haemolymph, but was less obvious in hepatopancreas, gill, and carapace. Both haemolymph and gill cadmium were inversely related to tissue calcium concentrations. Postmolt crabs exposed to 2.3 mg Cd/l for 6 days in 100% SW accumulated up to 5.0 mg Cd/l and up to 960 mg Ca/l in haemolymph, which was more than intermolt animals. Postmolt crabs in Cd-free seawater contained 350 to 585 mg Ca/l in haemolymph, generally lower than intermolts. Rise in Ca levels in the presence of cadmium may indicate some degree of competition for deposition sites between Cd and Ca.

2528. Yamamoto, T., Y. Otsuka, and K. Uemura. 1976. Gallium content in seaweeds. Jour. Oceanogr. Soc. Japan 32:182-186.

Gallium content of 30 species of seaweeds from near Tomo Island, Wakayama Prefecture ranged from 0.02 to 0.64 mg/kg dry wt with an average of 0.14 mg/kg. Aluminum, ranging from 57 to 3290 mg/kg dry wt, averaged 533 mg/kg; iron, ranging from 47-3310 mg/kg dry wt, averaged 501 mg/kg in seaweeds. Gallium content had a close relationship to Al and Fe. The average weight ratio of Ga/Al was 3.8×10^{-4} and ratio of Ga/Fe was 4.0×10^{-4}. Fe/Al ratio was 0.96. Ga/Al weight ratio was similar to that reported for shallow water deposits (2.1×10^{-4}), but was lower than in seawater (1.5×10^{-2}).

2529. Young, D.R., and T.-K. Jan. 1977. Fire fallout of metals off California. Marine Poll. Bull. 8:109-112.

Major forest or brush fires near highly-industrialized areas may create significant inputs of trace contaminants to coastal ecosystems by remobilizing metals previously deposited on land and foliage through aerial fallout. Trace metal quantities, in ug, obtained over a 7-day interval in 3 post-fire fallout samples from 0.075 m^2 dishes were Ag 0.005, Cd 0.098, Cr 0.40, Cu 4.0, Fe 300.0, Mn 5.8, Ni 0.78, Pb 12.0, and Zn 18.0. However, with the exception of iron, manganese and lead, estimated inputs of metals to the coastal marine ecosystem via this route during both fire and non-fire periods were one to two orders of magnitude lower than the submarine discharge of municipal wastewater.

2530. Zafiropoulos, D. and A.P. Grimanis. 1977. Trace elements in Acartia clausi from Elefsis Bay of the Upper Saronikos Gulf, Greece. Marine Poll. Bull. 8:79-81.

The planktonic copepod A. clausi is abundant in polluted areas of the Mediterranean; therefore it may play an important role in cycling and redistribution of trace elements in this ecosystem and may also prove to be a useful trace element indicator organism. Mean concentrations, in mg/kg dry wt, of 12 trace elements found in A. clausi from Elefsis Bay as determined by neutron activation were: As 2.9, Cd 0.61, Co 0.28, Cr 3.2, Cu 55.3, Fe 738.0, Hg 0.29, Mn 9.3, Sb 0.31, Sc 0.04, Se 1.8, and Zn 1270.0. Most concentrations were higher in January/74 than in February/74 probably owing to termination of active vertical convection. Higher levels of Co, similar levels of Fe and slightly decreased levels of Cr were recorded in A. clausi from the Bay of Roguebrune. Slightly decreased concentrations of Sb and Zn as well as higher concentrations of As and Cd were found in other copepods.

2531. Zauke, G.-P. 1977. Mercury in benthic invertebrates of the Elbe estuary. Helgol. wiss. Meeresunters. 29:358-374.

In general, mercury residues from benthic invertebrates of the Elbe estuary were highest at limnic sites and lowest at marine locations. Maximum Hg concentrations were found in the crustacean Asellus aquaticus and gastropod Radix balthica collected upstream from Hamburg, at 0.35 and 0.34 mg/kg wet wt, respectively. Concentrations in gammarid crustacean species decreased from 0.20 mg Hg/kg wet wt in the limnic region to 0.02-0.05 in brackish and marine waters. Geographical distribution of Hg in crustaceans was similar to that in the clay fraction of sediments, which may reflect actual Hg levels in this ecosystem. Mercury levels in organisms from the brackish region were: 0.08-0.16 mg/kg wet wt for the mollusc Littorina littorea; 0.04-0.09 for shrimp Crangon crangon; 0.05-0.10 for crustacean Corophium volutator; and 0.04-0.08 for the annelid Nereis diversicolor. Other crustaceans, bivalves, polychaetes, and fish were also analyzed for Hg. These concentrations were compared to levels found in organisms from other areas. Factors which influence heavy metal accumulations in aquatic organisms are discussed, including food chain, weight of organism, and elimination via molting in crustaceans.

2532. Zavodnik, N. 1977. Note on the effects of lead on oxygen production of several littoral seaweeds of the Adriatic Sea. Botanica Marina XX:167-170.

The influence of lead, ranging from 0.1 to 1.0 mg/l, on oxygen production of seaweeds was studied over 6 days in 37 o/oo S at 15 C. In Fucus virsoides, oxygen production was slightly reduced from 0.41 to 0.31 ml O_2/g/hr; and in Ulva rigida, from 1.53 to 1.21 in light as Pb levels increased. Rates generally decreased from day 1 to 6. Production rates in dark gave lower, but similar, results. Padina pavonia and Laurencia obtusa did not adapt to Pb exposure and showed signs of decay within 3 days. Author concludes that Pb ion concentrations in the 0.1-1.0 mg/l range are below levels detectably toxic to the investigated algae in short term tests.

2533. Zitko, V. and W.G. Carson. 1977. Seasonal and developmental variation in the lethality of zinc to juvenile Atlantic salmon (Salmo salar). Jour. Fish. Res. Bd. Canada 34:139-141.

The incipient lethal level (ILL) of zinc to juvenile Atlantic salmon in freshwater at a water hardness of 14 mg/l varies from 150 to 1000 ug/l as a function of season and developmental stage of the fish. The ILL increases from 500 to 1000 ug/l during the 1st yr and decreases to 150 ug/l in the following spring. The more sensitive stage in the salmon's life history, evidenced by decrease of ILL, coincides with and is probably related to initial stages of the parr-smolt transformation.

2534. Zitko, V. 1976. Structure-activity relations and the toxicity of trace elements to aquatic biota. In: Andrew, R.W., P.V. Hodson, and D.E. Konasewich (eds.). Toxicity to biota of metal forms in natural water. Great Lakes Res. Adv. Bd., Stand. Comm. Sci. Basis Water Qual. Criteria Inter. Jt. Comm. Res. Advis. Bd.:9-32.

Toxicity of inorganic Cu, Pb, Cd, Zn, Be, Ni, Ca, Sr, Mg, Mn, Co, Ba, Hg, Cd, As, Sb, Bi, V, Nb, Ta and other compounds to aquatic life is influenced by intrinsic toxicity of the element and availability to aquatic life as determined by occurrence, complexation and other chemical reactions, and adsorption. Glycine binding constants of metal cations may be correlated to their toxicity, as shown with copepod, fish, and mussel examples. Bicarbonate binding and competition for active sites are suggested as mechanisms for the decrease of toxicity of cations with increasing hardness of water. Analogous mechanisms may control the effects of organic compounds on toxicity of cations to aquatic biota.

2535. Anderson, P.D. and L.J. Weber. 1976. The multiple toxicity of certain heavy metals: additive actions and interactions. In: Andrew, R.W., P.V. Hodson, and D.E. Konasewich (eds.). Toxicity to biota of metal forms in natural water. Great Lakes Res. Advis. Bd., Stand. Comm. Sci. Basis Water Qual. Criteria Inter. Jt. Comm. Res. Adv. Bd.:263-282.

When aquatic organisms are exposed to several discrete toxicants in receiving waters containing anthropogenic wastes, there is the possibilty of interplay of toxic agents, either kinetic (uptake, accumulation, elimination) or dynamic (mode of action). Mixtures of copper and nickel, alone and with other chemical pollutants, exhibited strict additivity, or acted similarly, on survival of mature male guppies Poecilia reticulata over 96 hours. Mixtures of zinc and copper acted synergistically on guppies; lethal potency increased 2.5X over predictions on basis of strict additivity.

2536. Andrew, R.W. 1976. Toxicity relationships to copper forms in natural waters. In: Andrew, R.W., P.V.

Hodson, and D.E. Konasewich (eds.). Toxicity to biota of metal forms in natural water. Great Lakes Res. Adv. Bd., Stand. Comm. Sci. Basis Water Qual. Criteria Inter. Jt. Comm. Res. Adv. Bd.:127-143.

LC-50 (96 hr) values for fathead minnows increased to 25 mg Cu^{2+}/l as total phosphate rose to 7.0 mg P/l. Daphnia magna survival time increased to 544 min in 4.0 mg Cu^{2+}/l as added $NaHCO_3$ rose to 10 mM. Toxicity was directly related to the ionic activity of cupric ion, Cu^{2+}, at a given pH. Author suggests that increasing Cu^{2+} toxicity at high pH resulted from interactions with sulfhydral-containing proteins or enzymes. Biological reactivity, and thus toxicity to minnows, was limited by bicarbonate alkalinity, pyrophosphate, or orthophosphate; Ca and Mg had no effect. Copper complexes such as soluble $CuCO_3$ or Cu NTA's were much less toxic to aquatic organisms than cupric ions. Precipitates of copper were rather biologically active or toxic.

2537. Bass, E.L. 1977. Influences of temperature and salinity on oxygen consumption of tissues in the American oyster (Crassostrea virginica). Comp. Biochem. Physiol. 58B:125-130.

Oxygen consumption in oysters acclimated to 10 o/oo S rose to 1400 ul/hr per g in gill tissues over 21 days, higher than in 20 or 30 o/oo S at 500-800 ul/hr per g. Oxygen consumption of mantle tissues was also higher when acclimated to 10 o/oo S, reaching 1000 ul/hr per g after 10 days. In 20 and 30 o/oo S, rate was fairly constant at 400 over 21 days. No significant differnces were observed in muscle tissues of oysters exposed to different salinities; consumption rate remained at about 50 to 80 ul/hr per g.

2538. Beasley, T.M., M. Heyraud, J.J.W. Higgo, R.D. Cherry, and S.W. Fowler. 1978. ^{210}Po and ^{210}Pb in zooplankton fecal pellets. Marine Biology 44:325-328.

Mean concentrations of Po-210 and Pb-210 in fecal pellets from zooplanktonic euphausiids, Meganyctiphanes norvegica, collected between Monaco and Nice, France, were 49 dpm/gm dry wt for Po and 23 dpm/gm dry wt for Pb. The Po-210:Pb-210 activity ratio of 2.2 is close to that found in suspended particulate matter in surface seawater. Estimates of Po-210 and Pb-210 removal times from mixed layers by fecal pellets alone are the same order of magnitude as removal times by all routes. Authors suggest that zooplanktonic fecal pellets play a significant role in removal of these nuclides from ocean surface layers.

2539. Bissonnette, P. 1977. Extent of mercury and lead uptake from lake sediments by chironomids. In: Drucker, H. and R.E. Wildung (eds.). Biological implications of metals in the environment. ERDA Symp. Ser. 42:609-622. Avail. as CONF-750929 from Nat. Tech. Inf. Serv., U.S. Dept. Comm., Springfield, VA 22161.

Average metal concentrations in sediments from four lakes in western Washington were 0.48 mg Hg/kg dry wt and 24.7 mg Pb/kg dry wt (A), 0.42 Hg and 17.6 Pb (B), 0.24 Hg and 13.6 Pb (C), and 0.5 Hg and 11.7 Pb (D). Metal levels were higher in the middle of the lakes than at peripheries, due to particle size. Metal content in chironomid insects from the respective lakes were 0.06 mg Hg/kg dry wt and 4.2 mg Pb/kg dry wt (A), 0.12 Hg and 1.7 Pb (B), 0.03 Hg (C), and 0.30 Hg and 2.3 Pb (D). Concentration ratios of organism to sediment for all lakes ranged from 0.55 to 37.5 for mercury and from 0.24 to 6.3 for lead. Chiromid insect larvae, which constitute the bulk of the benthic biomass and food source for fish, are potential links between high sediment mercury and lead concentrations and predators.

2540. Brown, L.M. and J.A. Hellebust. 1978. Ionic dependence of deplasmolysis in the euryhaline diatom Cyclotella cryptica. Canadian Jour. Botany 56:408-412.

Cells of C. cryptica became plasmolyzed when subjected to a sudden increase in extracellular osmotic pressure from 0.3 to 1.0 osmol/l. Protoplasts regained their original volume if certain ions were present in the plasmolyzing solution. KCl was the most important ion, being the only electrolyte allowing deplasmolysis when supplied alone at 2000-8000 mg K^+/l. Cells did not deplasmolyze without KCl. Ca^{2+} at 440 mg/l, Mg^{2+} at 1340 mg/l, and Na^+ at 11,500 mg/l were necessary for high rates of deplasmolysis. Neither light nor ouabain had any effect on deplasmolysis rate; 2,4-dinitrophenol acted as a reversible inhibitor. Deplasmolysis appeared to be based on energy-dependent uptake of KCl, which is affected by Na^+ and divalent cations.

2541. Brown, V.M. 1976. Aspects of heavy metals toxicity in fresh waters. In: Andrew, R.W., P.V. Hodson, and D.E. Konasewich (eds.). Toxicity to biota of metal forms in natural water. Great Lakes Res. Adv. Bd., Stand. Comm. Sci. Basis Water Qual. Criteria Inter. Jt. Comm. Res. Adv. Bd.:59-75.

Heavy metal contamination of waters, toxicity of heavy metals to aquatic biota, and chemical states of metals in natural waters is discussed. Man-induced rates of mobilization of metals in fresh waters is 100X greater than geological rates for Sn, 30X for Sb, 11-13X for Pb, Fe, Cu, and Zn, and 1-4X for Mo, Mn, Hg, Ag, and Ni. Arsenic, Ba, Cd, Cr, Se, and V are also of environmental concern. Water conditions and complexing of metals effect biocidal properties of these elements. Median survival period for fish in 0.05 mg Cu/l was <300 min at pH 7.5 and 1000 min at pH 6.5. LC-50 (48 hr) varied from 0.004 mg Cu/l at pH 7.5 to 0.04 mg/l at pH 6.5. In hard water where Cd is present exclusively as the ionic form, exposure to 0.001-0.002 mg Cd/l for months affected reproduction of rainbow trout; histopathological changes occurred at 0.008 mg Cd/l. Author suggests that "acceptable" metal levels determined do not consider possible indirect effects to biota or effects of mixture of chemicals.

2542. Brungs, W.A., J.H. McCormick, T.W. Neiheisel, R.L. Spehar, C.E. Stephan, and G.N. Stokes. 1977. Effects of pollution on freshwater fish. Jour. Water Poll. Control Feder. 49:1425-1493.

A literature review of pollution effects to freshwater fishes, amphibians, echinoderms, molluscs, crustaceans, and protozoa is presented for Am, As, Cd, Ca, Cs, Cr, Co, Cu, Fe, La, Pb, Mg, Mn, Hg, Mo, Ni, Pu, K, Ra, Sc, Se, Ag, Na, Sr, U, Y, and Zn. Water quality data, salinity, pesticides, and domestic, industrial and radioactive pollutants are also discussed.

2543. Castilla, J.C. and E. Nealler. 1978. Marine environmental impact due to mining activities of El Salvador copper mine, Chile. Marine Poll. Bull. 9:67-70.

Untreated mining wastes discharged from the El Salvador copper mine directly onto the Chilean shore at Caleta Palito have hindered harbor activities, caused geomorphological coastal modifications, and affected marine coastal ecosystems and recreational activities. Tailing discharges are accumulating at 25,000 tons of fine sediment daily, plus unknown quantities of copper, arsenic, and cyanide. From Jan. 1975 to July 1976, this site received over 13 million tons of sediments. Massive fish and shellfish mortalities were reported in Feb. 1975, a few days after initiation of discharging. In July 1975 and July 1976, massive mortality was detected in intertidal and subtidal areas. Species affected were starfish *Stichaster striatus*, limpets *Collisella* spp., *Fisurella* spp., sea urchin *Tetrapigus niger*, crabs *Hemigrapsus crenulatus*, *Homolaspis plana*, barnacle *Concholepas concholepas*, and fishes *Sicyases sanguineus*, *Aphos porosus*, as well as several species of algae. A variety of invertebrates and fishes not found at Caleta Palito were present at Pan de Azucar about 25 km away.

2544. Caviglia, A. and F. Cugurra. 1978. Further studies on the mercury contents in some species of marine fish and molluscs. Bull. Environ. Contamin. Toxicol. 19:528-537.

Mercury levels were determined in 53 species of marine fish and molluscs from the Ligurian Sea, Italy, in 1974 and 1975. Samples of 11 species, *Aristeomorpha foliacea*, *Arnoglossus* sp., *Eledone* sp., *Etmospterus spinax*, *Gaidropsarus* sp., *Maena maena*, *Noephrops norvegicus*, *Pagrus pagrus*, *Penaeus keraturus*, *Serranus cabrilla*, and *Trachurus* sp., contained maximum levels of 0.73 to 2.50 mg Hg/kg wet wt, or levels that were in excess of the legal admissable tolerance limit in Italy of 0.7 mg/kg wet wt. In 7 other species, *Conger conger*, *Octopus vulgaris*, *Scomber scombrus*, *Scyllarus* sp., *Serranus scriba*, *Solea vulgaris*, and *Sphyrema sphyrema*, maximum total mercury content of 0.51 to 0.7 mg Hg/kg was determined. This is in excess of the 0.5 mg/kg wet wt limit imposed in the USA, Canada, and other countries. Mean mercury concentrations in the remaining species of fish and molluscs ranged from 0.02 to 0.46 mg Hg/kg wet wt. Possible sources of mercury pollution in Liguria are noted.

2545. Chynoweth, D.P., J.A. Black, and K.H. Mancy. 1976. Effects of organic pollutants on copper toxicity to fish. *In*: Andrew, R.W., P.V. Hodson, and D.E. Konasewich (eds.). Toxicity to biota of metal forms in natural water. Great Lakes Res. Adv. Bd., Stand. Comm. Sci. Basis Water Qual. Criteria Inter. Jt. Comm. Res. Adv. Bd.:145-157.

Mortality of guppies *Lebistes reticulatus* after 96 hr exposure to copper was 76-88% in 0.170-0.175 mg Cu/l, 85-100% in 0.192-0.216 mg Cu/l, and 83-100% in 0.232-0.235 mg Cu/l. Relative toxicity of copper to guppies decreased in 36 x 10^{-6}M NTA, EDTA, and glycine and in 5.0 mg/l total organic matter of humic acid; LC-50 (96 hr) values ranged from 0.183 to 0.224 mg Cu/l compared to controls of 0.112-0.138 mg/l. Egg albumin and sewage effluent at 5.0 mg organic matter/l increased toxicity with LC-50 (96 hr) values of 0.102 and 0.099 mg Cu/l, respectively, while 36 x 10^{-6}M cysteine had no effect. An inverse relationship was observed between degree of copper binding and Cu toxicity. Organic binding and toxicity was not correlated to Cu uptake by fish.

2546. Conway, H.L. 1978. Sorption of arsenic and cadmium and their effects on growth, micronutrient utilization, and photosynthetic pigment composition of *Asterionella formosa*. Jour. Fish. Res. Bd. Canada 35:286-294.

Sorption of arsenic by freshwater diatom populations exposed for up to 22 days, rose linearly to 0.035 mg As/10^{12} um^3 as As concentration increased to 0.13 mg/l, then plateaued. Cadmium sorption was a function of ambient levels and time; maximum bioaccumulation rate was 17,000, with 0.34 mg Cd/10^{12} um^3 during immersion in 19.6 mg Cd/l for 2 days. Cellular As and Cd were desorbed in some cases, and there appeared to be an active regulatory mechanism keeping As at a non-toxic level. No detrimental effects on growth, or nitrate, phosphate, and silicate utilization were observed in all experimental As levels up to 0.16 mg/l. Ambient concentrations of 0.002 mg Cd/l, however, reduced population growth rate by an order of magnitude; populations exposed to >0.01 mg Cd/l ceased growth and micronutrient utilization in 20-30 hrs. By following radio-labelled metals, cellular As was found to associate with the organic layer surrounding the frustule, while Cd associated with cell contents.

2547. Cross, F.A., J.N. Willis, L.H. Hardy, N.Y. Jones, and J.M. Lewis. 1975. Role of juvenile fish in cycling of Mn, Fe, Cu, and Zn in a coastal-plain estuary. *In*: Cronin, L.E. (ed.). Estuarine Research, *vol. 1*. Chemistry, biology, and the estuarine system. Academic Press, Inc., N.Y.: 45-63.

Daily flux of manganese, iron, copper and zinc was estimated for fish during summer months in the Newport River estuary, North Carolina, from the equation I = A + E. Ingestion rate of metal (I) was determined by rate of food consumption multiplied by metal concentration in stomach contents. Assimilation rate (A) was the sum of increase rate of metal body burden and rate of metal loss in biological turnover. Egestion rate of unassimilated metal (E) was estimated by subtracting (A) from (I). Mean concentration levels found in juvenile fish stomach contents were: 110 mg Zn/kg dry wt, 22,000 mg Fe/kg, 270 mg Mn/kg, and 25 mg Cu/kg for menhaden *Brevoortia tyrannus*; 620 mg Zn/kg dry wt, 26,000 Fe, 520 Mn, and 92 Cu for spot *Leiosotomus xanthurus*; and 75 mg Zn/kg dry wt, 5200 Fe, 55 Mn, and 13 Cu for pinfish *Lagodon rhomboides*. Flux of Zn in fish showed an assimilation efficiency of 36% in menhaden which accumulated 1.67 ug/day in tissues, 2% efficiency in spot which accumulated 0.6 ug/day, and 19% efficiency in pinfish which accumulated 0.58 ug/day. Assimilation efficiency of Fe was 1% in menhaden, 0.3% in spot, and 0.6% in pinfish; respective tissue accumulation was 10.0, 3.6, and 1.5 ug/day. Mn assimilation efficiency was 3.0% in menhaden, 0.7% in spot, and 7.0% in pinfish, with tissue accumulations of 0.28, 0.19, and 0.17 ug/day, respectively. Cu assimilation efficiency was 9.0% in menhaden, 1.0% in spot, and 2.9% in pinfish; accumulation was 0.09, 0.05, and 0.04 ug/day, respectively. Flux of metals in the estuary through whole juvenile populations of each species was also calculated.

2548. Davey, E.W. 1976. Potential roles of metal-ligands in the marine environment. *In*: Andrew, R.W., P.V. Hodson, and D.E. Konasewich (eds.). Toxicity to biota of metal forms in natural water. Great Lakes Res. Adv. Bd., Stand. Comm. Sci. Basis Water Qual. Criteria Inter. Jt. Comm. Res. Adv. Bd.:197-209.

Population growth of the marine diatom *Thalassiosira pseudonana* from 2500 to 40,000 cells/ml over 45 days in controls was reduced to 7500 cells/ml over 45 days as copper concentration rose to 0.01 mg/l. In 0.02 to 0.05 mg Cu/l, population size increased to only 3500 to 4500 cells/ml. *T. pseudonana* populations exposed to 0.01 mg Cu/l alone decreased to 5-15% of control numbers. Addition of 1 x 10^{-7}M EDTA slightly increased diatom tolerance. In 5 x 10^{-7}M EDTA or 5.5 x 10^{-7}M histidine, diatom population size stayed within 90% of controls in 0.02 mg Cu/l; size declined to 15% in 0.05 mg Cu/l. *T. pseudonana* tolerated copper exposure better in relatively unpolluted seawater than water from a polluted industrial area.

Author concluded that it is not necessarily total metal amounts present, but the form of metal, that determines its biological action.

2549. Davies, P.H. 1976. The need to establish heavy metal standards on the basis of dissolved metals. In: Andrew, R.W., P.V. Hodson, and D.E. Konasewich (eds.). Toxicity to biota of metal forms in natural water. Great Lakes Res. Adv. Bd., Stand. Comm. Sci. Basis Water Qual. Criteria Inter. Jt. Comm. Res. Adv. Bd.:93-126.

In water with hardness of 385 mg/l as $CaCO_3$ at 14 C, all rainbow trout died when exposed to 5.29 and 6.54 mg Pb/l for 4 days. In 0.79 mg Pb/l 30% died, but no mortality was observed in 0.48 mg/l. In hard water with 290 mg $CaCO_3$/l at 7 C, all trout were killed in 2.85 to 7.56 mg Pb/l over 4 days, 30% died in 1.30 mg Pb/l, and none died in 0.25 mg/l. In soft water with 32 mg $CaCO_3$/l at 10 C, 85% of the trout died in 1.60 mg Pb/l over 4 days, 5% died in 0.43 and 0.78 mg Pb/l, and all survived in 0.13 and 0.22 mg/l. LC-50 (96 hr) values for trout in hard water were 471 mg/l total Pb or 1.47 mg/l dissolved Pb; in soft water, this was 1.17 mg/l total (or dissolved) Pb. Concentrations of 0.12-0.36 mg total Pb/l or 0.02-0.03 mg dissolved Pb/l in hard water, and 0.007-0.015 mg Pb/l in soft water were not fatal. The LC-50 (96 hr) cadmium concentration was 1.75 ug/l in soft water. No effect was seen in 0.7-1.5 ug Cd/l in soft water or 13.5-21.0 ug Cd/l in hard water. After one year exposure to silver, 38% mortality of trout was observed after "swim-up" in 0.50 ug Ag/l, 24.5% in 0.32 ug/l, 19% in 0.18 ug/l, and 3% in 0.13 ug/l. Use of dialysis tubing and filtration to distinguish dissolved and complexed metal forms, and effects of pH on metal speciation are discussed.

2550. Eaton, J.G., J.M. McKim, and G.W. Holcombe. 1978. Metal toxicity to embryos and larvae of seven freshwater fish species—I. cadmium. Bull. Environ. Contamin. Toxicol. 19:95-103.

Minimum cadmium concentrations at which fish standing crop was significantly lower than controls were determined. For each species, exposure to Cd was up to 10 days as embryos and 27 to 33 days as larvae-juveniles. Deleterious cadmium concentrations were 11.2 to 12.9 ug Cd/l for white sucker *Catostomus commersoni*, northern pike *Esox lucius*, smallmouth bass

Micropterus dolomieui, lake trout *Salvelinus namaycush*, and late eyed embryo of brown trout *Salmo trutta*. A concentration of 3.4 ug Cd/1 was deleterious to Lake Superior coho salmon *Oncorhynchus kisutch*. Mortality in lake trout exposed for 64 days as larvae was not different than that for shorter exposure; however, lethal concentration dropped to 3.7 ug/1 in late brown trout embryos exposed for 61 days. Populations of coho salmon decreased in 12.5 ug Cd/1 when exposed for 20 days as embryos and 27 or 62 days as larvae. For brook trout *Salvelinus fontinalis* exposed for 24 days as embryos and 31, 65, or 126 days as larvae these values were 0.5 to 11.7 ug Cd/1. In brown trout exposed for 50 days as embryos and 33 or 60 days as larvae this value was 11.7 ug Cd/1. Larvae or juveniles were more sensitive than embryos in all cases.

2551. Fletcher, P.E. and G.L. Fletcher. 1978. The binding of zinc to the plasma of winter flounder (*Pseudopleuronectes americanus*): affinity and specificity. Canadian Jour. Zoology 56:114-120.

The binding affinity of winter flounder plasma proteins for zinc was determined by equilibrium dialysis. Percentage of bound Zn^{2+} dropped sharply from 100 to 35% as total zinc present rose to 200 ug/1. A Rosenthal type plot indicated more than one binding site for zinc. The association constant, 10^7-10^8, was similar to that of mammalian serum albumin. It required twice the normal total plasma zinc concentration to saturate the higher affinity binding system. All plasma Zn was removed by dialyzing with 0.01 M histidine. Cu^{2+} competed significantly with Zn binding to plasma; competition was diminished with Tris buffer. Cd^{2+}, Ca^{2+}, Co^{2+}, Cr^{2+}, Fe^{2+}, Hg^{2+}, Mg^{2+}, Mn^{2+}, and Ni^{2+} had no effect on binding of Zn^{2+} to the plasma. EDTA had a greater effect on Zn binding than predicted from its theoretical binding capacity for zinc. Percentage of Zn-65 bound to plasma was only 33.6% with 0.0048 uMol EDTA, compared to 99.7% without EDTA.

2552. Fletcher, G.L. and M.J. King. 1978. Seasonal dynamics of Cu^{2+}, Zn^{2+}, Ca^{2+}, and Mg^{2+} in gonads and liver of winter flounder (*Pseudopleuronectes americanus*): evidence for summer storage of Zn^{2+} for winter gonad development in females. Canadian Jour. Zoology 56:284-290.

Male and female gonads of winter flounder initiated development in August and spawned in June. Maximum testes weight was observed in October, corresponding to the end of experimental feeding period. Maximum ovary weight was not observed until February, indicating that ovarian growth occurred after feeding ceased. Zinc, Cu, Ca and Mg exhibited seasonal variations in gonads and livers. Total ion accumulation of zinc reached 6.0 mg/kg body wt in ovaries in Feb. and 2.0 mg/kg in testes in Nov.; copper reached 0.15 mg/kg body wt in ovaries in March and 0.03 mg/kg in testes in Nov.; and calcium reached 11.0 mg/kg body wt in ovaries in Mar. and 5.0 mg/kg in testes in Nov. Testes accumulated more Mg than ovaries: 0.024 mg/kg body wt in male gonads in Dec. and 0.021 mg/kg in females in April. Ovaries continued to incorporate all four elements after flounder ceased eating; levels in liver decreased from winter months to April. Some Zn^{2+} and Cu^{2+} requirements could have been met by utilizing liver stores, although most Zn was probably obtained from other storage areas. The source of the ovaries postfeeding requirements for Ca^{2+}, Cu^{2+}, and Mg^{2+} could have been metal absorption from seawater by flounder.

2553. Fox, F.R. and K.R. Rao. 1978. Characteristics of a Ca^{2+}-activated ATPase from the hepatopancreas of the blue crab, Callinectes sapidus. Comp. Biochem. Physiol. 59B:327-331.

Calcium-activated ATPase from crab hepatopancreas required 800 mg Ca/l for maximal activity of 0.35 umoles P/mg protein/min. Magnesium, at up to 240 mg/l, was less effective in activating ATPase; barium was also a relatively poor activator. The maximal activity evoked by strontium alone was greater than Ca^{2+}. Potassium was not required for activation. Enzyme activity due to 95 mg Mg/l alone was significantly lower than that produced by 800 mg Ca^{2+}/l alone, but mixtures of 1370 mg Ba^{2+}/l and 800 mg Ca^{2+}/l, or 875 mg Sr^{2+}/l and 800 mg Ca^{2+}/l were associated with elevated values. Combinations of Ca with K, Na, or Mg produced no significant difference in activity. The K_m of the Ca-activated enzyme for ATP was 4.1×10^{-3} M. Maximal activity was noted at 45-50 C and pH 7.5.

2554. Friedman, M.A., L.R. Eaton, and W.H. Carter. 1978. Protective effects of freeze dried swordfish on methylmercury chloride toxicity in rats. Bull. Environ. Contamin. Toxicol. 19:436-443.

Average body weight in rats fed a 15% casein or 15% freeze dried swordfish diet for 10 days was 350-375 gms; with 20 mg/kg methyl HgCl added to each diet, body weight was 200-225 gms. In another study, all 10 rats died between 2 and 5 weeks when fed 40 mg Hg/kg with either diet. Five rats died between 7 and 10 wks when fed 15% casein and 20 mg Hg/kg; only 2 died with 15% swordfish and 20 mg Hg/kg. Neurotoxic behavior appeared in all rats fed 40 mg Hg/kg after 6 wks; effects were observed first in animals eating casein rather than swordfish. Ten percent showed toxic effects by 10 wks with 20 mg Hg/kg and casein, but not with swordfish. Freeze dried swordfish protected rats from methylmercury. Swordfish contained 0.30 to 1.67 mg Hg/kg and 0.79 to 4.84 mg Se/kg; Hg content paralleled fish size but did not correlate to solid content. Selenium was assumed to be the protective agent against Hg, although protein and caloric content also differed between the two diets.

2555. Greichus, Y.A., A. Greichus, B.D. Ammann, and J. Hopcraft. 1978. Insecticides, polychlorinated biphenyls, and metals in African lake ecosystems. III. Lake Nakuru, Kenya. Bull. Environ. Contamin. Toxicol. 19:454-461.

Average metal concentrations in water column (mg/l) and bottom sediments (mg/kg dry wt) of Lake Nakuru, Africa, were 0.006 and 35.0 for arsenic, 0.021 and 0.27 for cadmium, 0.002 and 6.2 for copper, 0.024 and 550.0 for manganese, 0.005 and 34.0 for lead, 0.049 and 140.0 for zinc, and < 0.001 and 0.26 for mercury. Among organisms collected from the lake, arsenic concentrations of 7.5 mg/kg dry wt were determined for chironomid insects, 0.14 in other aquatic insects, and 1.80 in fish; cadmium at 0.19 mg/kg dry wt, 0.45, and 0.26, respectively; copper at 4.6 mg/kg dry wt, 11.0, and 10.0, respectively; manganese at 78.0 mg/kg dry wt, 12.0, and 19.0, respectively; lead at 1.3 mg/kg dry wt, 0.82, and 0.84, respectively; zinc at 61.0 mg/kg dry wt, 70.0 and 110.0, respectively; and mercury at 0.26 mg/kg dry wt, 0.16, and 0.22 in respective groups. Cadmium levels were higher than reported for other African lakes. Insecticide and polychlorinated biphenyl concentrations are also listed.

2556. Greichus, Y.A., A. Greichus, H.A. Draayer, and B. Marshall. 1978. Insecticides, polychlorinated biphenyls and metals in African lake ecosystems. II. Lake McIlwaine, Rhodesia. Bull. Environ.

Contamin. Toxicol. 19:444-453.

Average metal concentrations in Lake McIlwaine were: As 0.003 mg/l and 37.0 mg/kg dry wt in bottom sediment, Cd 0.001 mg/l and 0.39 mg/kg sediment, Cu 0.010 mg/l and 38.0 mg/kg sediment, Mn 0.032 mg/l and 350.0 mg/kg, Pb 0.010 mg/l and 41.0 mg/kg, Zn 0.012 mg/l and 100.0 mg/kg, and Hg $<$ 0.001 mg/l and 0.28 mg/kg sediment. Organisms from the lake contained arsenic at 2.9 mg/kg dry wt in plankton, 6.0 in oligochaetes, 1.3 in benthic insects, and 1.4 in fish; cadmium at 1.5 mg/kg dry wt, 0.05, 0.08, and 0.12, respectively; manganese at 220 mg/kg dry wt, 28.0, 8.8, and 27.0, respectively; lead at 78.0 mg/kg dry wt, 1.3, 0.91, and 0.84, respectively; zinc at 190 mg/kg dry wt, 130, 78, and 48 in respective organisms; mercury at 0.26 mg/kg dry wt in plankton, 0.08 in oligochaetes, and 0.23 in fish; and copper at 7.2 mg/kg dry wt in oligochaetes, 10.0 in benthic insects, and 5.4 in fish. Average concentrations in cormorants from Lake McIlwaine were 1.4 mg/kg dry wt in carcass, 0.94 in brain, and 1.2 in feathers for As; 0.04, 0.10, and 0.38, respectively, for Cd; 3.1, 9.0, and 8.7 for Cu; 4.9, 1.6, and 21.0 for Mn; 2.7, 1.3, and 2.4 for Pb; 77, 33, and 180 for Zn, and 2.8, 1.3 and 0.65 in respective tissues for Hg. Levels of polychlorinated biphenyls and insecticides in Lake McIlwaine and its organisms are also listed.

2557. Greig, R.A., D.R. Wenzloff, C.L. MacKenzie, Jr., A.S. Merrill, and V.S. Zdanowicz. 1978. Trace metals in sea scallops, Placopecten magellanicus, from eastern United States. Bull. Environ. Contamin. Toxicol. 19:326-334.

Metal concentrations in sea scallops collected from 42 stations in the North Atlantic between Cape Hatteras and George's Bank were: $<$ 0.08 to 0.24 mg Ag/kg wet wt in muscle, 0.13 to 0.69 Ag in gonads, and 0.22 to 1.9 Ag in visceral mass; $<$ 0.06 to 0.12 mg Cd/kg wet wt in muscle, 0.47 to 3.2 in gonads, and 3.7 to 27.0 in visceral mass; $<$ 0.26 to 0.64 mg Cr/kg wet wt in muscle, $<$ 0.29 to 1.7 in gonads, and 0.37 to 4.0 in visceral mass; 0.27 to 1.1 mg Cu/kg wet wt in muscle, 1.1 to 10.6 in gonads, and 1.3 to 5.6 in visceral mass; $<$ 0.08 to 0.18 mg Hg/kg wet wt in all tissues; $<$ 0.26 to 0.68 mg Ni/kg wet wt in muscle, 0.23 to 2.5 in gonads, and 0.31 to 1.6 in visceral mass; $<$ 0.4 to 1.7 mg Pb/kg wet wt in muscle, $<$ 0.44 to 1.5 in gonads, and 0.45 to 1.6 in visceral mass; and 2.0 to 8.1 mg Zn/kg wet wt in muscle, 4.7 to 75.4 in gonads, and 7.4 to 22.5 in visceral mass. Most metals, except Zn, were below detection limits in muscle. Silver, Cd, Cu, and Zn were generally detectable in gonads; females had higher concentrations of Cu and Zn than males. Only Hg and Pb were below detection in muscle and most concentrations were similar to gonadal levels.

2558. Hamanaka, T., H. Kato, and T. Tsujita. 1977. Cadmium and zinc in ribbon seal, *Histriophoca fasciata*, in the Okhotsk Sea. Res. Inst. N. Pac. Fish., Hokkaido Univ., Spec. Vol.:547-561.

Ribbon seals *Histriophoca fasciata*, harbor seals *Phoca vitulina largha*, and ringed seals *Pusa hispida*, collected off Sakhalin Island, Japan, in 1975, contained 0.31 to 1.10 mg Cd/kg dry wt and 34.0 to 171.0 mg Zn/kg dry wt in muscle; 1.37 to 11.0 and 111 to 264, respectively, in liver; 1.57 to 6.69 and 43 to 124, respectively, in spleen; 0.91 to 6.33 and 81 to 106, respectively, in pancreas; 0.35 to 3.59 and 47 to 176, respectively, in stomach wall; and 0.14 to 0.19 and 1.8, respectively, in fat. Male and female ribbon seals showed no significant differences in metal content of muscle. Maximum cadmium and zinc levels occurred in ribbon seal liver; high pancreas Cd content suggests this organ is important for metal storage along with kidney and liver. Cadmium in harbor seals was lower than ribbon seals, partially due to their diet of fish rather than squid (which have high liver Cd). Pacific cod, *Gadus macrocephalus*, contained 0.14 mg Cd/kg dry wt in muscle and 0.17 in liver; and 6.5 mg Zn/kg in muscle, 79 in gonad, and 18 in liver. Squid, *Ommastrephes bartrami*, contained 0.72 mg Cd/kg dry wt in muscle, 0.35 in gonads, and 80.6-85.5 in muscle; and 54 mg Zn/kg in muscle, 73 in gonads, and 115-124 in liver.

2559. Hamdy, M.K. and N.V. Prabhu. 1978. Behavior of mercury in bio-systems. II. depuration of $^{203}Hg^{2+}$ in various trophic levels. Bull. Environ. Contamin. Toxicol. 19:365-373.

Effects of temperature and form of Hg-203 ion on depuration of mercury by bacteria *Bacillus licheniformis*, mosquito *Aedes aegypti* larvae, and guppies *Lebistes reticulatus* were investigated. Rate of biological elimination (k) of organic $C_6H_5Hg\text{-}203OCCH_3$ by bacteria at 4 C was -0.24/day and of inorganic $Hg\text{-}203(NO_3)_2$ was -0.44/day. At 23 C, 37 C, and 45 C, elimination rate increased to between -0.09 and -0.23/day for organic Hg and -0.23 and -0.26/day for inorganic Hg. Biological half-life of Hg-203 ion in bacteria generally

Hg-203 ion in bacteria generally decreased with rising temperature from 11.8 to 4.5 days for organic and from 22.3 to 17.8 days for inorganic Hg. Elimination rate of organic Hg-203 in mosquito larvae at 27 C was -0.22/day; k was rapid at -0.08/day for inorganic Hg-203. Half-lives were 11.2 days organic and 4.1 days inorganic Hg. In guppies at 23 C, k was -0.14/day for organic and -0.13/day for inorganic Hg; respective half-lives were 7.2 days and 6.5 days. Bacteria cells washed with water retained 35% organic and 25% inorganic Hg-203 after 5 rinses. After 5 washes with 0.05 Na phosphate buffer, retention was 50% organic and 55% inorganic Hg-203.

2560. Hartung, R. 1976. Pharmacokinetic approaches to the evaluation of methylmercury in fish. In: Andrew, R.W., P.V. Hodson, and D.E. Konasewich (eds.). Toxicity to biota of metal forms in natural water. Great Lakes Res. Adv. Bd., Stand. Comm. Sci. Basis Water Qual. Criteria Inter. Jt. Comm. Res. Adv. Bd.:233-248.

Mathematical models were appplied to describe uptake, distribution, storage, and elimination kinetics of mercury in several species of freshwater fishes using previous laboratory and field studies. Uptake differences between species were not significant. Temperature effects, possibly due to metabolic rate, were pronounced and systematic. Author suggests that bioaccumulation experiments may be more precise and their duration shortened under certain conditions, and that comparisons between experimental and monitoring data may be improved.

2561. Hendricks, A.C. 1978. Response of Selenastrum capricornutum to zinc sulfides. Jour. Water Poll. Control Feder. 50:163-168.

Oxygen production by algae, S. capricornutum, was decreased by 50% after 4 hr exposure to 1.0 mg Zn/l and to 2.5 mg/l of sulfide. In 1.5 and 2.5 mg Zn/l, oxygen production was only 10% compared to controls, while production was 75 to 115% in 0.75 mg Zn/l. When Zn and S were added at a 2:1 ratio, oxygen production was near control rates even with 5.0 mg Zn/l and 2.5 mg S/l. Lowest production rates were obtained at the extreme ratios of 1:2 or 5:1 Zn to S. Results show zinc and sulfide act antagonistically to reduce their toxic effects.

2562. Herricks, E.E. 1977. Effects of pollution on freshwater invertebrates. Jour. Water Poll. Control Feder. 49:1493-1506.

Studies of effects of metals and various chemicals and oils to freshwater bacteria, protozoans, sponges, coelenterates, rotifers, platyhelminthids, annelids, molluscs, crustaceans, insects, fishes, and birds are reviewed. Toxicity, bioaccumulation, and community effects are discussed for silver, cadmium, cobalt, chromium, copper, iron, mercury, potassium, sodium, nickel, lead, ruthenium, and zinc.

2563. Hildebrand, S.G., A.W. Andren, and J.W. Huckabee. 1976. Distribution and bioaccumulation of mercury in biotic and abiotic compartments of a contaminated river-reservoir system. In: Andrew, R.W., P.V. Hodson, and D.E. Konasewich (eds.). Toxicity to biota of metal forms in natural water. Great Lakes Res. Adv. Bd., Stand. Comm. Sci. Basis Water Qual. Criteria Inter. Jt. Comm. Res. Adv. Bd.:211-232.

Dissolved mercury appeared to be leaching from waste ponds at an abandoned chlor-alkali plant on the Holston River in Tennessee during 1973 and 1974. Water above the plant contained 0.036-0.048 ug/l total mercury and 0.013-0.016 ug/l dissolved mercury. Maximum values of Hg were found at the waste pon[illegible] with 0.203 ug/l total and 0.174 ug/l dissolved. Mercury levels 120 km downstream were similar to those above the plant. In sediments, 20.7 mg total Hg/kg was found at the pond, compared to 0.24-0.32 upstream. Sediment Hg levels generally remained < 1.0 mg/kg for 250 km below the plant. Methylmercury was not detected in sediment. Total mercury in axial muscle of fishes Ambloplites rupestris, Hypentelium nigricans and Notropis spp. was 0.28-0.70 mg/kg wet wt above the plant, 1.42-1.70 mg/kg at the pond, and 0.43-1.26 mg/kg 135 km downstream; >78% was as methylmercury at all locations. A composite of benthic invertebrate taxa, primarily insects and crustaceans, contained an average of 0.05 mg Hg/kg wet wt in whole animals upstream from the plant, 1.55 mg/kg at the pond, 0.79 mg/kg 20 km downstream and 0.20 mg/kg 135 km below the plant. Methylmercury accounted for 44.7-56.5% of the total Hg body burden. Dietary uptake by fish feeding on benthic invertebrates is considered an important route for methylmercury.

2564. Hoppenheit, M. 1977. On the dynamics of exploited populations of Tisbe holothuriae (Copepoda, Harpacticoida). V. the toxicity of cadmium: response to sub-lethal exposure. Helgol. wiss. Meeresunters. 29:503-523.

Populations of copepods, T. holothuriae, were exposed to 0.148 or 0.222 mg Cd^{2+}/1, combined with weekly exploitation rates of 10, 30, 50, 70, or 90% over 70 weeks. Cadmium addition prolonged and reinforced downward trends of the normal U-shaped density patterns. Age structures shifted more toward nauplii as population densities fell below a certain value; more pronounced reductions did not increase the nauplii fraction. Within 23 weeks (20 generations), effects of Cd^{2+} on copepod densities were counteracted by metal acclimation. No relationship was seen between exploitation rate and population density. Possible limitations of the significance of results and revisions on the adaptability of parametric methods on dispersion of data are discussed.

2565. Ishii, T., H. Suzuki, and T. Koyanagi. 1978. Determination of trace elements in marine organisms - I factors for variation of concentration of trace element. Bull. Japan. Soc. Sci. Fish. 44:155-162. (In Japanese).

Marine fishes from the Japanese coast showed only small variations in metal concentrations; however, invertebrates and algae showed marked species specificity. The teleosts Paralichthys olivaceus, Argyrosomus argentatus, Hexagrammos otakii, Sebastes thompsoni, [illegible] nivosus, Lateolabrax japonicus, Seriola quinqueradiata, and Evynnis japonica contained metal concentrations, in mg/kg dry wt muscle, [illegible] 0.31 to 0.79 for Mn, 6.1 to 23.0 Fe, 0.007 to 0.022 Co, 0.31 to 0.59 Ni, 0.51 to 1.61 Cu, 16.0 to 39.0 Zn, 2.4 to 4.0 Rb, and 0.06 to 0.18 [illegible] Copper and Zn showed regional variation. Among invertebrates, soft parts of the mussel Mytilus corscum contained maximum concentrations of Mn at 7.7 mg/kg dry wt, Fe at 150.0, and Zn at 160.0; clam Gomphina melanaegis contained maximum Co at 0.70 mg/kg dry wt, Ni at 3.2, and Rb at 5.2; squid Sepia esculenta contained maximum Cu at 35.0 mg/kg dry wt, and prawn Penaeus japonica contained maximum Cs at 0.046 mg/kg dry wt. The stomatopod Squilla oratoria, clam Meretrix lamarckii, and snail Notohaliotis discus were also analyzed. Maximum metal concentrations, in mg/kg dry wt, in marine algae were 6.0 for Ni, 14.0 for Cu, and 170.0 for Zn in Chodrus ocellatus; 41.0 for Mn and 0.07 for Cs in Sargassum thunbergi; 590.0 for Fe in

Sargassum thunbergi; 590.0 for Fe in *Ulva pertusa*; 52.0 for Rb in *Hizikia fusiforme*; and 0.43 for Co in *Sargassum kjellmanianum*. Also analyzed were *Enteromorpha* sp., *Ahnfeltia paradoxa*, *Undaria pinnatifida*, *Eisenia bicyclis*, *Sargassum sagamianum*, *S. ringgoldianum*, and *S. horneri*. For most metals, concentrations in algae increased with distance from the growing tip; this was especially pronounced for Fe. Iron levels tended to decrease with increasing growth of algae but other metals varied little. Seasonal variations showed maximum Fe, Co, and Zn concentrations in March in *Sargassum*. Maximum concentration factors for marine organisms were 9000 for Mn, 10,000 for Fe, and 40 for Rb in *Sargassum*; 4000 for Co, 100 for Ni, 4000 for Cu, and 4000 for Zn in shellfish; and 70 for Cs in fish muscle.

2566. Kari, T. and P. Kauranen. 1978. Mercury and selenium contents of seals from fresh and brackish water in Finland. Bull. Environ. Contamin. Toxicol. 19:273-280.

Mercury and selenium concentrations in seal *Phoca hispida* muscle caught in 1974 and 1975 from Bothnian Bay in the Baltic Sea were 0.47-1.16 mg Hg/kg wet wt and 0.44-0.92 mg Se/kg wet wt; 14-300 for Hg and 6.1-110.0 for Se in liver, and 2.8-5.2 for Hg and 2.5-3.3 for Se in kidney. In *P. h. saimensis* from Lake Saimaa, Finland, metal concentrations were 1.3-6.1 mg Hg/kg wet wt and 0.24-2.8 mg Se/kg wet wt in muscle, 72-210 for Hg and 29-170 for Se in liver, 1.9-13 for Hg and 0.34-3.0 for Se in kidney, and 0.14-0.46 for Hg and 0.06-0.11 for Se in blubber. Correlation coefficients between Hg and Se tissue contents were high in liver of all seals, but levels in kidney, flesh, and muscle were not strongly correlated. Baltic herring, pike, vendace, and whitefish, all potential food sources for seals in Bothnian Bay, contained 0.09-0.23 mg Hg/kg wet wt and 0.24-0.50 mg Se/kg wet wt in muscle; burbot from a Hg-polluted area contained 1.0 mg Hg/kg and 0.21 mg Se/kg. Metal contents in roach, perch, and vendace from Saimaa were 0.12-0.26 mg Hg/kg and 0.29-0.43 mg Se/kg in muscle and 0.07-0.22 for Hg and 0.37-0.50 for Se in whole fish.

2567. Kayser, H. 1977. Effect of zinc sulphate on the growth of mono- and multispecies cultures of some marine plankton algae. Helgol. wiss. Meeresunters. 30:682-696.

Effects of up to 5 mg/l zinc sulphate on multiplication rate, in vivo chlorophyll fluorescence, maximum cell densities, and species equilibrium were investigated in cultures of dinoflagellates Scrippsiella faeroense, Prorocentrum micans, and Gymnodinium splendens, and of diatoms Schroederella schroederi and Thalassiosira rotula. In monocultures, inhibition occurred in 0.01 to 0.10 mg Zn/l over 38 days. Diatoms were more sensitive than dinoflagellates. Sensitivity to zinc increased with the number of species combined. In a 5 species culture, sublethal changes appeared at 0.005 to 0.010 mg Zn/l. Schroederella and Thalassiosira populations were reduced to 24% and 71%, respectively. Interspecific competition and Zn toxicity both decreased algal growth. At low cell numbers resulting from competition, zinc effects were seen only in higher concentrations of 5.0 to 10.0 mg/l. Morphological aberrations were observed in Scrippsiella at 1.0 mg Zn/l and in diatoms at 0.01 mg/l. Results show that multispecies experiments are a more sensitive test for zinc toxicity than monocultures. Author suggests that heavy metal toxicity may become effective at lower limit concentrations in natural planktonic communities.

2568. Kunze, J., H. Buhringer, and U. Harms. 1978.
Accumulation of cobalt during embryonic development of rainbow trout (Salmo gairdneri Rich.) Aquaculture 13:61-66.

During incubation at 8 C in rearing water containing 0.5 ug Co/l and calcium content of 100 mg/l, trout eggs contained between 0.0003 and 0.0013 ug Co/egg through hatching. In 5.0 ug Co/l and 100 mg Ca^{2+}/l, eggs accumulated up to 0.0033 ug Co/egg by the eyed stage; larvae contained only 0.0005 ug after hatching. Uptake of cobalt-57 by eggs exposed to 1000 ug Co/l varied inversely with Ca^{2+} water levels. By the eyed stage, eggs had accumulated up to 20,000 counts/min/egg in 50 mg Ca/l, up to 13,000 in 100 mg Ca/l, and up to 10,000 in 200 mg Ca/l; Cobalt levels dropped to 5000-10,000 just before hatching. Bivalent Co ions were reversibly bound to egg surfaces by the binding force of chorion-mucopolysaccharide. No increase in Co was found in larvae hatched from these eggs.

2569. Lakshmi, G.J., A. Venkataramiah, and H.D. Howse. 1978.
Effect of salinity and temperature changes on spontaneous muscle necrosis in Penaeus aztecus Ives. Aquaculture 13:35-43.

Spontaneous muscle necrosis or appearance of irregular white foci in abdominal segments was studied in brown shrimp, P. aztecus, in relation to salinity and temperature changes. Shrimp were acclimated at 17 o/oo S, or 50% SW, and exposed to salinities considered sub-optimal (0.34-3.4 o/oo S), optimal (8.5-17.0 o/oo S), or supra-optimal (42.5-59.5 o/oo S). In optimal salinity, 1.0-2.7% shrimp developed necrosis in 21 to 31 C, but all survived. In low salinity, 6.7% developed necrosis at 21 C within minutes, 8.0% at 31 C, and all died at both temperatures; 4.0% were afflicted at 26 C with 78% mortality. In high salinity, 10.5% shrimp showed necrotic symptoms at 21 C with 80% mortality, and 13.6% affected at 31 C with 87% mortality; 1.0% were afflicted at 26 C with 67% dead. Incidence of necrosis and subsequent mortality was directly related to magnitude of salinity and temperature change. Histopathological studies of necrotic muscles showed no pathogens.

2570. Leland, H.V., S.N. Luoma, and D.J. Wilkes. 1977. Heavy metals and related trace elements. Jour. Water Poll. Control Feder. 49:1340-1369.

Surveys from literature of trace metal concentrations in freshwater and marine plankton, algae, and higher plants, annelids, bacteria, bryophytes, coelenterates, crustaceans, echinoderms, insects, molluscs, nematodes, protozoans, fishes, birds, and mammals are listed. Toxicity, bioaccumulation, and biomagnification in these organisms is discussed. Also reported are metal concentrations in seawater and sediments from around the world. Metals mentioned include Ag, Al, As, B, Be, Bi, Ca, Cd, Co, Cr, Cs, Cu, Eu, Fe, Ge, Hg, K, Li, Mg, Mn, Mo, Na, Ni, Pb, Pu, Rb, Sb, Sc, Se, Si, Sn, Th, Ti, Tl, V, and Zn.

2571. Luoma, S.N. and E.A. Jenne. 1977. The availability of sediment-bound cobalt, silver, and zinc to a deposit-feeding clam. In: Drucker, H. and R.E. Wildung (eds.). Biological implications of metals in the environment. ERDA Symp. Ser. 42:213-230. Avail. as CONF-750929 from Nat. Tech. Inf. Serv., U.S. Dept. Comm., Springfield, VA 22161.

Availability of sediment-bound Co, Zn, and Ag to clams, Macoma balthica, was dependent on physical and chemical natures of the metal-sediment association. Uptake of zinc coprecipitated with amorphic iron oxide sediment exhibited a concentration factor (CF) for dry clam tissue to dry sediment of 0.003-0.009 after 14 days, and with manganese oxide sediment, a CF of 0.006-0.007. Cobalt had a CF of 0.002-0.005 and 0.001-0.002 for the respective sediment sinks, which are common in nature. Silver was accumulated by *Macoma* from iron oxide precipitate by a factor of 0.04-0.15. *All* metals were taken up from detrital organics; CF for Ag was 0.03, 0.08-0.12 for Zn, 0.02-0.05 for Co. Quantitatively minor sinks in aquatic sediments may be important sources of metals. Uptake rates for Zn with a CF of 0.13-0.19, and Co with a CF of 0.07-0.10, from biogenic carbonates (crushed clam shells) were significantly higher than other sinks. Silver uptake was maximum from biogenic carbonates, at 0.3-0.8, and synthetic calcites, at 3.7-6.1. Sinks with maximum metal bioaccumulation also had greatest rates of sediment-to-water desorption. When such sinks are abundant in nature, bioavailability of sediment-bound metals may be enhanced through uptake of injested particles by deposit feeders and through sedimentary desorption, resulting in higher concentrations of solute metals.

2572. Madgwick, J., A. Haug, and B. Larsen. 1978. Ionic requirements of alginate-modifying enzymes in the marine alga *Pelvetia canaliculata* (L). Dcne. et Thur. *Botanica Marina XXI:1-3.*

A stable, semi-pure, freeze-dried powder containing alginate 5-epimerase and alginate lyase activity was prepared from a brown alga. Maximal epimerase activity was at 136 mg Ca^{2+}/l and at 5490 mg Mn^{2+}/l. Alginate lyase activity was activated by 136 Ca^{2+}/l but was inhibited by Mn^{2+}. Ion combinations of 136 mg Ca/l and 549 mg Mn/l were optimal for epimerisation, but inhibited lyase activity by 90% of Ca^{2+} alone. Increasing concentrations of substrate polymannuronate removed Mn inhibition of lyase. Zinc at 654 mg/l and nickel at 587 mg/l strongly inhibited both enzymes; 589 mg/l cobalt suppressed lyase but did not affect epimerase. Magnesium, sodium, cesium, potassium, rubidium, and lithium did not signficantly alter activities.

2573. Martin, J.H., K.M. Bruland, and W.W. Broenkow. 1976. Cadmium transport in the California Current. *In:* Windom, H.L. and R.A. Duce (eds.). Marine pollutant transfer. D.C. Heath and Co., Lexington, MA: 159-184.

Cadmium levels in seawater from 95 sites off the California coast ranged from 0.016 to 0.156 ug/l at the interface, and generally increased from 0.0039-0.027 ug Cd/l to 0.0051-0.124 ug/l with increasing depth to 90 m. Cadmium levels were directly proportional to phosphate and nitrate concentrations in waters except in the Southern California Bight area. Metal concentrations reached a maximum at 20 m at one station analyzed; Cd rose to 0.150 ug/l, Cu to 0.240 ug/l, Pb to 0.525 ug/l, Mn to 0.600 ug/l, Ni to 0.825 ug/l, and Zn to 4.500 ug/l. Plankton collected from Southern California waters contained 0.03 to 0.51 mg Ag/kg, 13.0 to 3710.0 Al, < 3.0 to 737.0 Ba, 7800 to 33,700 Ca, 2.2 to 24.7 Cd, 2.9 to 17.7 Cu, 36 to 3870 Fe, 3600 to 13,800 K, 6100 to 26,400 Mg, 3.5 to 35.9 Mn, 50,900 to 250,000 Na, 2.1 to 18.5 Ni, 0.8 to 13.6 Pb, 3000 to 242,000 Si, 1000 to 16,800 Sr, and 3.2 to 86.9 Zn.

2574. McKim, J.M., J.G. Eaton, and G.W. Holcombe. 1978. Metal toxicity to embryos and larvae of eight species of freshwater fish - II: copper. Bull. Environ. Contamin. Toxicol. 19:608-616.

Standing crops of freshwater fishes exposed to various concentrations of copper as embryos, larvae, and early juveniles, were compared to controls. Rainbow trout *Salmo gairdneri* numbers reduced to 10% after exposure to 30 ug Cu/l of embryos for 11 days, or 35 days for larvae-juvenile; white sucker *Catostomus commersoni* reduced to 30% after 13 day embryo and 27 day larvae-juvenile exposure to 30 ug/l. Brook trout *Salvelinus fontinalis* populations after 16 day embryo exposure and 60 day larvae-juvenile exposure, and lake trout *S. namaycush* after 27 day embryo and 66 day larvae-juvenile exposure to 50 ug Cu/l dropped to 60% of controls; lake trout further reduced to 40% in 120 ug/l. A concentration of 100 ug Cu/l was fatal to rainbow trout, brook trout, sucker, and pike; 450 ug Cu/l killed all lake trout. Standing crop of trout exposed to 50 ug Cu/l for 127 days was reduced to 40% of control values; these values were 80% and 100% of control values at 97 and 71 days, respectively. All brook trout died in 110 ug Cu/l after 127 days and in 500 ug/l after 97 and 71 day exposures. Concentrations of 104 ug Cu/l and higher reduced standing crop of lake herring *Coregonus artedi*, and smallmouth bass *Micropterus dolomieui* after 30 days. Larvae and early juvenile stages of all species were more sensitive to copper than embryos.

2575. Mearns, A.J. and D.R. Young. 1977. Chromium in the southern California marine environment. *In*: Giam, C.S. (ed.). Pollutant effects on marine organisms. D.C. Heath and Co., Lexington, MA: 125-142.

Marine life in coastal waters of southern California is naturally exposed to approximately 0.2 ug/l of dissolved chromium: 0.15 ug Cr^{6+}/l and 0.05 ug Cr^{3+}/l. Uncontaminated sediments contain up to 40,000 ug Cu/kg dry wt. Chromium from municipal wastewater, mainly bound to particulates, contaminates sediments by 20X and seawater by 2 to 5X near outfalls. Most chromium is in the Cr^{3+} form. In 1972, the State of California established a limit of 5.0 ug/l total Cr for discharges into coastal water up to 50% of the time and 10.0 ug/l not to exceed 10% of the time. Adductor muscles of scallops showed a 10X enhancement of Cr in response to wastewater discharge. Total chromium concentrations in the polychaete annelid Neanthes arenaceodentata after 150 days increased to 30,000 ug/kg dry wt when placed in media containing up to 30 ug Cr^{6+}/l. LC-50 values of Cr^{6+} to Neanthes were 2200-4300 ug/l at 96 hr, 1440-1890 ug/l at 7 days, and 200 ug/l at 59 days. Spawning ceased in 100 ug Cr^{6+}/l and reduction in brood size was observed at 12.5 to 50.0 ug/l. After 44 days, flounders Citharichthys stigmaeus contained 100,000 ug Cr/kg dry wt in intestine, 10,000 in liver, and 3000 in muscle when exposed to up to 3000-5000 ug/l. Fish accumulated Cr during long term exposure at levels as low as 16 ug Cr/l. Most tissues in fish, except gonads, remained at ambient Cr levels despite exposure to contaminated sediments. In contrast to Cr^{+6}, Cr^{3+} was not toxic to marine life, possibly due to its relative insolubility at normal pH of seawater.

2576. Meier-Brook, C. 1978. Calcium uptake by Marisa cornuarietis (Gastropoda;Ampullariidae), a predator of schistosome-bearing snails. Archiv fur Hydrobiologie 82:449-464.

Marisa is a predatory gastropod which vigorously feeds on intermediate host snails of schistomes and other trematodes and shows a high net uptake of calcium from the water, up to 400 ug/individual/hr or more. Uptake is about 20X higher than Biomphalaria glabrata, an important snail host of intestinal schistosomiasis. Results suggest that Marisa is unable to establish its life cycle in tropical soft water containing suboptimal levels of Ca, where its application as a biological control agent would be desirable. Net Ca uptake of Marisa aged 12 to 25 weeks varied between 0.20 and 0.45 mg Ca^{2+}/individual/hr in 100 mg Ca/l water. Net Ca uptake was significantly reduced in $<$ 50 or 75 mg Ca/l. Acclimation to 25 mg Ca/l for $5\frac{1}{2}$ weeks led to an increase of net uptake of 0.30 mg/ind/hr when transferred to 70 mg Ca/l. Growth of Marisa increased when reared in 100 rather than 25 mg Ca/l; shells in 100 mg/l gained 41% more weight over 33 weeks.

2577. Meisch, H.-U. and J. Bauer. 1978. The role of vanadium in green plants. IV. influence on the formation of δ-aminolevulinic acid in Chlorella. Arch. Microbiology 117:49-52.

Vanadium, at 20.0 ug V/l as NH_4VO_3, enhanced synthesis of δ-aminolevulinic acid (δ-ALA) in green alga Chlorella pyrenoidosa, as evidenced by increased release of this amino acid into the medium in the presence of levulinic acid (LA). Exogenous levels of δ-ALA after 5 days in media of pH 6.0 were 2.7 mg/l without V and 10.4 mg/l with 20.0 ug V/l in presence of 34 mM LA; % δ-ALA/algal dry wt was 0.3 without V and 0.9 with V. Levels of δ-ALA were significantly lower at pH 7.0 and 7.5. Intracellularly accumulated levels of δ-ALA increased only slightly with added vanadium. Vanadium uptake without LA dropped from 13.4 mg V/kg dry wt to 4.5 over 6 days; with 34 mM LA, uptake ranged from 9.1 to 10.7 mg V/kg dry wt over this period. Authors suggest that vanadium acts as a catalyst in converting 4,5-dioxovaleric acid to δ-ALA by transamination.

2578. Meisch, H.-U. and H. Benzschawel. 1978. The role of vanadium in green plants. III. influence on cell division of Chlorella. Arch. Microbiology 116:91-95.

Vanadium, although essential for growth and chlorophyll formation in green algae, exhibited deleterious effects on cell division of Chlorella pyrenoidosa over the same concentration range as positive effects. It has been shown that 1.0 ug V/l increased algal dry wt, 500 ug/l promoted chlorophyll synthesis, but above 25,000 ug/l vanadate is toxic to algal metabolism. Cell volume of Chlorella grown in 20.0 ug$_3$V/l, as NH_4VO_3, was evenly distributed over the 200 to 1600 um^3 range. Without V, most cells were smaller, 200-650 um^3 after 3 days and 100-400 um^3 after 7 days. Mean cell volume increased to 1500 um^3 as V added to medium rose to 500 ug/l, then dropped to 920 um^3 in 100,000 mg V/l; mean volume was 320 um^3 in the absence of vanadium. Uptake by Chlorella rose to 100% of applied dose after 24 hrs under continuous light, and up to 60% by 28 hrs in the dark. Under synchronous conditions of algal cultivation (16:8 hr), V completely arrested cell division after 3 periods; this stop lasted for the next 3 cycles. Later asynchronous divisions led to larger autospores and giant nuclei with multiple chromosome sets. Under these conditons, C. pyrenoidosa is not synchronizable in presence of vanadium.

2579. Montgomery, J.R., M. Price, J. Thurston, G.L. de Castro, L.L. Cruz, and D.D. Zimmerman. 1978. Biological availability of pollutants to marine organisms. U.S. Environ. Protect. Agen. Rept. EPA-600/3-78-035, Narragansett, R.I.:134 pp.

Uptake rates of Cd, Cr, Cu, Ni, Pb, and Zn leached from sewage sludge by seawater by a turtle grass, Thalassia testudinum, ecosystem were studied. Cadmium, Pb, and Zn uptake in the "fouling organisms" closely paralleled net loss of metals from sewage sludge. Thalassia leaves contained up to 3 mg Cd/kg dry wt above control values during 120 days exposure to sludge, up to 35 mg Cu/kg, up to 60 mg Cr/kg, up to 80 mg Pb/kg, up to 45 mg Ni/kg, and up to 25 mg Zn/kg. The urchin Lytechinus variegatus, a herbivore which consumes Thalassia leaves, showed net uptakes of all metals except Cd over 120 days: 15 mg Cu/kg dry wt, 45 mg Cr/kg, 30 mg Pb/kg, 30 mg Ni/kg, and 70 mg Zn/kg. The sea cucumber Holothuria mexicana accumulated metals up to 30 mg Cu/kg dry wt, 40 mg Cr/kg, 65 mg Pb/kg, 40 mg Ni/kg, and 50 mg Zn/kg, but did not accumulate Cd. Maximum uptake in mangrove Rhizophora mangle roots was 5 mg Cu/kg dry wt, 25 mg Cr/kg, 5 mg Pb/kg, 10 mg Ni/kg, and 20 mg Zn/kg. Uptake in mangrove roots was directly related to sediment metal concentration. No significant metal uptake was found in the clam Codokia orbicularis, oyster Crassostrea rhizophora, or snail Nerita tessplata, possibly due to lack of sufficient sample mass. Authors concluded that dumping of sewage sludge in coastal tropical waters may lead to uptake and concentration of toxic metals by members of a turtle grass community.

2580. Moore, M.N. 1977. Lysosomal responses to environmental chemicals in some marine invertebrates. In: Giam, C.S. (ed.). Pollutant effects on marine organisms. D.C. Heath and Co., Lexington, MA: 143-154.

Cytoplasmic lysosomes in the hydroid Campanularia flexuosa and mussel Mytilus edulis accumulate various metal ions. Maximum activity of the enzyme lysosomal hexosaminidase in Campanularia, as shown by staining intensity, increases to

180-200% over controls at 50 ug Cu/l, 100 ug Cd/l, or 0.5 ug Hg/l. Further increase in metal levels sharply decreased activity. Cytochemical thresholds of the lysosomal enzyme were at 1.2-1.9 ug Cu/l, 40-75 ug Cd/l, and 0.17 ug Hg/l. Addition of hydrocortisone decreased enzyme activity, with or without 20 ug Cu^{2+} in media.

2581. Neff, J.M. and J.W. Anderson. 1977. The effects of copper (II) on molting and growth of juvenile lesser blue crabs Callinectes similis Williams. In: Giam, C.S. (ed.). Pollutant effects on marine organisms. D.C. Heath and Co., Lexington, MA: 155-165.

Median LT-50 values in crabs, C. similis, exposed to 0.50 mg Cu/l were 3.7 days for megalops and 7.7 days for first crab stage. LT-50 in 0.25 mg Cu/l was 30 days for first crab stage. LT-0 and LT-100 in 0.50 mg Cu/l was 1 and 31 days, respectively, for megalops and 3 and 49 days for first crab stage. In 0.25 mg Cu/l, the LT-0 was 20 days and LT-100 was 68 days for first crabs. Death usually occurred during or immediately after a molt. No mortalites were observed for megalops or juveniles exposed to 0.05 mg Cu/l for 130 days. Chronic exposure to 0.05 mg Cu/l resulted in decreased intermolt periods, especially during later juvenile stages; however, growth rate was faster than controls. Average wet weight of crabs was reduced in 0.05 mg Cu/l. Results are discussed in relation to suspected modes of toxic action of copper in marine animals.

2582. Nimmo, D.R., R.A. Rigby, L.H. Bahner, and J.M. Sheppard. 1978. The acute and chronic effects of cadmium on the estuarine mysid, Mysidopsis bahia. Bull. Environ. Contamin. Toxicol. 19:80-85.

Mysid shrimp, M. bahia, showed no significant decrease in survival when exposed to 4.8 or 6.4 ug Cd/l for 23 days under flow-through conditions. Only 10% survived in 10.6 ug Cd/l for 23 days; none survived after 13 days in 28.0 ug/l. LC-50 values were 15.5 ug Cd/l for 96 hrs and 11.3 ug/l during a 17-day life history exposure. Mysids were more sensitive to cadmium than other crustaceans: selected species had LC-50 (96 hr) values extending from 120.0 to 720.0 ug Cd/l. Authors suggest that life-cycle bioassays can aid in establishing water quality criteria for marine and estuarine organisms.

2583. Oikari, A. 1978. Aspects of osmotic and ionic regulation in two Baltic teleosts: effects of salinity on blood and urine composition. Marine Biology 44:345-355.

Hydromineral regulation was studied in two species of brackish water teleosts, *Myoxocephalus scorpius* and *M. quadricornis*, in water ranging from freshwater to 33 o/oo S. *M. scorpius* tolerated freshwater and *M. quadricornis* tolerated seawater of 33 o/oo for only 24 hr; survival time of *M. scorpius* in 33 o/oo S and *M. quadricornis* in freshwater was up to several weeks. *M. scorpius* exhibited balanced plasma ionic concentrations at salinities as low as 2.5 o/oo during immersion for 2 weeks; some regulation was evident for Na^+, Cl^-, Mg^{2+}, and Ca^{2+}. Death of *M. scorpius* in freshwater was associated with increased plasma K^+ and decreased Na^+, Cl^-, and Mg^{2+} in plasma and to a lesser extent in urine, partial hemolysis, and increased red blood cell volume after 24 hrs. Death of *M. quadricornis* in 33 o/oo S was associated with increases in plasma Na^+, Cl^-, and Mg^{2+} and total osmolarity. Renal excretion of ions approached that of marine teleosts, showing reduced Na^+ and K^+ and elevated Cl^-, Mg^{2+}, and Ca^{2+} after 24 hrs. Red blood cell volume generally followed changes in plasma osmolarity or Na^+ and Cl^- concentrations, the most abundant ions in fish plasma and urine in most cases. Both species increased tubular Mg^{2+} secretion in 33 o/oo S when compared to 6 o/oo S; *M. quadricornis* reabsorbed Na^+ almost completely from urine.

2584. Osterberg, C. and S. Keckes. 1977. The state of pollution of the Mediterranean Sea. Ambio 6:321-326.

The Mediterranean is expected to be one of the first seas to suffer harm from man's impact because of its configuration and proximity to a number of more developed nations. Mercury levels as high as 2.5-3.5 mg/kg wet wt have been found in tuna in the Mediterranean, levels 3X higher than in Atlantic tuna. Cadmium in offshore waters are generally <0.003 mg/l. Water concentrations of copper increase markedly, up to 0.022 mg/l, in areas of land runoff. Mussels reflected this increase, containing 0.095 mg Cu/kg dry wt off Marseille, France. High levels of zinc, 0.20 mg/l, found in coastal areas drop to 0.005-0.015 mg/l in the open sea; Zn is rapidly removed by biota, dispersion, and diffusion. Little data are available on lead. Sewage and oil pollution appear to be the principal problems along the northwest Mediterranean basin.

2585. Pagenkopf, G.K. 1976. Zinc speciation and toxicity to fishes. *In*: Andrew, R.W., P.V. Hodson, and D.E. Konasewich (eds.). Toxicity to biota of metal forms in natural water. Great Lakes Research Adv. Bd., Stand. Comm. Sci. Basis Water Quality Criteria Inter. Jt. Comm. Res. Adv. Bd.:77-91.

Zinc speciation was calculated using data from literature dealing with Zn toxicity to fishes, mainly fathead minnows, bluegills, and rainbow trout. Calcium and magnesium in test waters reduced effects of Zn; concentrations for LC-50 (96 hr) rose as water hardness increased from 50 to 200 mg/l as $CaCO_3$. Increasing pH from 6 to 8 decreased LC-50 zinc concentrations 20-50X. Amounts of solid $ZnCO_3$ in water increased with this pH change; however, relative toxicity of solid and soluble Zn forms has not yet been established.

2586. Patrick, R. 1978. Effects of trace metals in the aquatic ecosystem. American Scientist 66:185-191.

Various concentrations of Cr, Se, and V may cause shifts in species composition of freshwater algal communities. Diatoms generally remained at control levels when exposed to 3.5 to 2000 ug V/l; however, growth declined slightly during one trial in Sept-Oct. in 8.9 and 19.2 ug V/l. Occurrence of diatoms was rare in 39 ug V/l in Sept.-Oct. and 4000 ug/l in Nov.-Mar. Blue-green algae were rare to frequent in lower concentrations of vanadium, and more common in 4000 ug/l than control medium. Green algae were rare in up to 39 ug V/l in Sept.-Oct., but common in 2000 and 4000 ug/l in Feb.-Mar. Algal biomass accumulation rose to 25,800 mg/kg in 4000 mg V/l, although concentration factors (CF) were maximum at 17,000 in lower concentrations. When exposed to chromium, diatoms were dominant in controls and 96-99.5 ug Cr^{6+}/l; green and especially blue-green algae became abundant in 376 and 405 ug Cr/l. The green alga, *Stigeoclonium lubricum*, was the most common in high Cr and V levels. Algal populations contained up to 3360 mg Cr^{6+}/kg in 376 ug/l; CF was over 29,000 in lower concentrations. Diatoms were common in all concentrations of selenium tested (1.0 to 40.5 ug/l) although diversity decreased at higher concentrations. Green and blue-green algae were common only during Apr.-May in 1.1 to 10.4 ug Se/l. As selenate, Se was toxic to diatoms at all concentrations tested. Maximum Se levels in biomass was 8800 mg/kg in 40 ug/l; maximum mg/kg in 40 ug/l; maximum CF was only 680 in the lowest concentration.

2587. Patterson, C., D. Settle, B. Scháule, and M. Burnett. 1976. Transport of pollutant lead to the oceans and within ocean ecosystems. In: Windom, H.L. and R.A. Duce (eds.). Marine pollutant transfer. D.C. Heath and Co., Lexington, MA: 23-38.

Approximate total lead inputs into oceans from all sources in tons/yr, were 300,000 from industrial inputs and 114,000 from neolithic inputs. Lead concentrations reported in coastal waters near urban regions ranged from 0.025 ug Pb/l to 0.150 ug/l in polluted areas. Surface waters off Los Angeles, California, in 1973-1975, had 0.11-0.33 ug Pb/l; 1.30 ug/l was detected at 30 m depth. Lead in surface waters at La Jolla and areas south of Los Angeles was 0.016-0.036 ug/l. As the proportion of sewage lead in seawater increases, fraction of freely available Pb decreases. Authors recommend that actual enrichment or depletion of lead in marine organisms be expressed relative to bulk of calcium. In a seawater - kelp Macrocystis pyrifera - gastropod Norrisia norrisii food chain, Sr/Ca ratio increased by 8, Ba/Ca by 20, and Pb/Ca by 2000 going from seawater to kelp. Metal concentrations were depleted using kelp for gastropod food: Sr/Ca decreased by 70, Ba/Ca by 600, and Pb/Ca by 150 for total gastropod. Ratios decreased by only 2.0-10.0 in reference of kelp to gastropod muscle. Metals present at the lowest and highest trophic levels in another food chain were: calcium, 400 mg/l in seawater and 8800 mg/kg wet wt in albacore tuna; strontium, 8.1 and 36.0 respectively; barium 0.03 and 0.1; and lead, 0.00002 and 0.008. Calcium ratios in albacore are lower than in a terrestrial food chain, possibly due to passive adsorption effects in the marine ecosystem.

2588. Pentreath, R.J. 1977. Radionuclides in marine fish. Oceanogr. Mar. Biol. Ann. Rev. 15:365-460.

Environmental levels and accumulation-retention studies of radionuclides of Ag, Am, As, Au, Ba, Bi, Ca, Cd, Ce, Cm, Co, Cr, Cs, Cu, Eu, Fe, Hg, K, La, Mn, Mo, Nb, Np, Pa, Pb, Po, Pr, Pu, Ra, Rb, Rh, Ru, Sb, Sc, Sr, Tc, Te, Th, Tl, U, W, Y, Zn, and Zr were reviewed for marine fishes. Concentration factors of stable Ag, Au, Ce, Co, Cr, Cs, Fe, Mn, Sb, Sr, and Zn in fish from different areas are listed. Author discusses the environmental application of metal levels determined. A bibliography of about 360 references is appended.

2589. Phillips, D.J.H. 1978. The common mussel Mytilus edulis as an indicator of trace metals in Scandinavian waters. II. lead, iron, and manganese. Marine Biology 46:147-156.

Metal concentrations in mussel soft parts from 54 locations in Scandinavian waters ranged from 3.0 to 264.0 mg/kg dry wt for lead, from 14.0 to 1367.0 mg/kg dry wt for iron, and from 4.9 to 91.7 mg/kg dry wt for manganese. Maximum Pb and Fe levels were found in mussels collected near an ironworks. In agreement with previously published data, indicator ability of mussels for Pb and Fe was supported over the entire salinity range; Mn indication appeared questionable at least in low salinity ranges. Higher concentrations of Pb and Fe were found in mussels from low salinity waters east of Sweden than mussels from higher salinity waters to the west. Mn tissue concentrations followed this trend only weakly, possibly owing to partial regulation of body loads in M. edulis. Low salinity waters seem to be associated with greater biological availability of Pb and Fe; this may be related to low primary productivity when compared to typically marine waters.

2590. Pirt, S.J. and M. Walach. 1978. Biomass yields of Chlorella from iron ($Y_{X/Fe}$) in iron-limited batch cultures. Arch. Microbiol. 116:293-296.

Biomass in iron-limited photosynthetic algal batch cultures of Chlorella increased as the logarithm of the iron concentration. Growth yield from iron ($Y_{X/Fe}$) was inversely related to specific growth rate. Maximum biomass yield, in mg dry wt/mg Fe consumed, was 7500 with specific growth rate 0.108/hr; minimum yield was 790 with growth rate 0.145/hr. Maximum specific growth rate in the exponential phase of Fe-limited cultures over 30 days was higher as initial Fe concentration was increased to 0.469 mg/l. Fe-limited growth made cells adhere to glass surfaces.

2591. Prater, B.L. and M.A. Anderson. 1977. A 96-hour bioassay of Otter Creek, Ohio. Jour. Water Poll. Contr. Feder. 49:2099-2106.

Bioassays of 96 hour duration were conducted using the crustacean *Daphnia magna*, the insect *Hexagenia limbata* and the isopod *Asellus communis* exposed to sediments from various locations along Otter Creek in Ohio. Less than 10% of each species died when exposed to sediments upstream from any industrial site. Sediments contained 23,000 mg Fe/kg dry wt, 17,000 mg Al/kg, 475 mg Mg/kg, 110 mg Zn/kg, 100 mg B/kg, 79 mg Pb/kg, and ≤30 mg/kg in decreasing order of Ni, Cr, Co, Cu, Cd, and As. Pretest water used in all trials contained 51 mg Ca/l, 13.6 mg Mg/l, 6.7 mg Na/l, 0.1 mg Sn/l and < 0.1 mg/l for Al, As, Ba, Be, B, Cd, Cr, Co, Cu, Fe, Pb, Mn, Hg, Mo, Ni, Ag, Ti, V, and Zn. Concentrations of other chemicals present are also listed. Most metal levels in solution increased during the experiment. Mortality among *Daphnia* was >95% when exposed to sediments from 4 other sites downstream from industrial and municipal outfalls. Sediments downstream from one industrial outfall killed 15-30% of *Hexagenia* and 35-45% of *Asellus*. After the second outfall, all *Hexagenia* and *Asellus* died in 96 hrs in sediments containing 28,000 mg Fe/kg dry wt, 14,000 mg Al/kg, 665 mg Mn/kg, 185 mg Cr/kg, 135 mg Zn/kg, 130 mg B/kg, and ≤ 70 mg/kg for other metals tested. Sediments downstream from the third outfall killed 60-80% of *Hexagenia* and 100% of *Asellus*; after the fourth outfall, 90-100% of *Hexagenia* and 100% of *Asellus* died after sediment exposure. Authors concluded that sediments in the lower two thirds of Otter Creek are not conducive to life support of aquatic biota.

2592. Ranta, W.B., F.D. Tomassini, and E. Nieboer. 1978. Elevation of copper and nickel levels in primaries from black and mallard ducks collected in the Sudbury district, Ontario. Canadian Jour. Zoology 56:581-586.

Primary flight feathers of black ducks, *Anas rubripes*, and mallard ducks, *A. platyrhynchos*, collected from northern Ontario and northern Saskatchewan, Canada, during fall 1975, were analyzed for copper, nickel, and zinc. Ducks collected 20 to 30 km from the Copper Cliff smelter, a known source of particulate fallout, contained 99 to 132 mg Zn/kg dry wt. Concentrations were 103 to 129 mg Zn/kg from ducks 50-60 km 117 to 130 mg/kg at 85 km, and 108 to 150 mg/kg at 95-140 km away from the smelter. Zinc was 101 to 144 mg/kg dry wt in ducks from from Saskatchewan as a control. Mean copper in birds ranged from 11 to 23 mg/kg dry wt with a high of 53 at 20-30 km from the smeltery, 9.0 to 19.0 mg/kg at 50-60 km, 11.0 to 24.0 mg/kg at 85 km, 5.0 to 17.0 mg/kg at 95-140 km, and 0.0 to 14.0 from Saskatchewan. Mean nickel concentrations ranged from 2.0 to 12.5 mg/kg dry wt, with a high of 36.7 at 20-30 km, 0.2 to 3.8 mg/kg at 50-60 km, 0.2 to 1.5 mg/kg at 85 km, 0.0 to

4.3 mg/kg at 95-140 km, and 0.0 to 0.4 mg/kg from Saskatchewan. Zinc concentrations did not vary with population sampled; mean copper, and especially nickel, levels were highest near the smelter in Sudsbury. No trends in metal levels were apparent with species, sex, age, or wing type analyzed.

2593. Ray, S. 1978. Bioaccumulation of lead in Atlantic salmon (*Salmo salar*). Bull. Environ. Contamin. Toxicol. 19:631-636.

Juveniles of 1470-1940 g wet wt, and parr of 8.0-18.4 g wet wt, from the Miramichi River, New Brunswick, Canada, in June 1974, were analyzed for lead. Muscle contained 0.02-0.17 mg Pb/kg dry wt in juveniles and 0.7-2.2 mg Pb/kg in parr; gill contained 1.9-7.5 and 6.6-20.6, respectively; liver, 1.5-11.2 and 16.4-139.6, respectively; kidney, 11.4-51.2 and 21.2-173.5, respectively; and spine, 0.4-1.2 and 4.1-13.1, in respective specimens. Lead concentrations in tissues from parr were 2.5 to 15X higher than juveniles.

2594. Rehwoldt, R.E., W. Mastrianni, E. Kelley, and J. Stall. 1978. Historical and current heavy metal residues in Hudson River fish. Bull. Environ. Contamin. Toxicol. 19:335-339.

Average metal concentrations, in ug/kg dry wt, in Hudson River fish from four information sources between 1924 and 1976 were: 91-120 for cadmium, 160-210 for mercury, and 300-610 for lead in alewife *Alosa pseudoharengus*; 96-110 for Cd, 310-460 for Hg, and 710-820 for Pb in sturgeon *Acipensor oxyrhynchus*; 12-72 for Cd, 140-240 for Hg, and 410-1100 for Pb in killifish *Fundulus diaphanus*; 41-72 for Cd, 520-610 for Hg, and 990-1060 for Pb in smallmouth bass *Micropterus dolomieui*; 71-160 for Cd, 160-220 for Hg, and 590-770 for Pb in shiner *Notropis hudsonius*; 43-99 for Cd, 320-510 for Hg, and 210-920 for Pb in striped bass *Morone saxatilis*; 260 for Cd, 420 for Hg, and 250 for Pb in sunfish *Lepomis gibbosus*; and 62-100 for Cd, 300-510 for Hg, and 800-1060 for Pb in perch *Morone americana*. Residues appeared to be independent of time or industrial development.

2595. Reish, D.J., T.J. Kauwling, A.J. Mearns, P.S. Oshida, and S.S. Rossi. 1977. Marine and estuarine pollution. Jour. Water Poll. Contr. Fed. 49:1316-1340.

A literature review on pollution effects to marine organisms by Ag, Al, As, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Pb, Mg, Mn, Na, Ni, Se, Si, Sr, Ti, Tl, Zn, petroleum, and several detergents and oil dispersants is presented. Data include natural residues and sublethal and lethal effects to algae, annelids, bacteria, crustaceans, echinoderms, fish, mammals, molluscs, and sipunculids.

2596. Rickard, W.H. and H.A. Sweany. 1977. Radionuclides in Canada goose eggs. *In*: Drucker, H. and R.E. Wildung (eds.). Biological implications of metals in the environment. ERDA Symp. Ser. 42:623-627. Avail. as CONF-750929 from Nat. Tech. Inf. Serv., U.S. Dept. Comm., Springfield, VA 22161.

Radionuclide levels, in pCi/kg ash wt, in Canada goose eggs from deserted nests along the Columbia River, Washington, in 1974 ranged from: 20,000 to 22,000 in inner egg contents and 3600 to 4200 in eggshells for K-40; 560 in eggs and 1300 to 1700 in shells for Sr-90; 170 to 6300 in eggs and 23 to 32 in shells for Cs-137; 230 to 430 in eggs and 180 in shells for Zn-65; 45 to 60 in eggs and 58 to 72 in shells for Ru-106; 70 in eggs and 27 to 81 in shells for Zr-Nb-95; and 28 to 39 in eggs and 5.0 to 8.0 in shells for Co-60. Inner egg contents also contained 41 to 104 pCi/kg Mn-54, 19 to 24 for Na-22, and 3.0 for Pu; eggshells contained 324 for Be-7 and 95 for Ce-144. Although Sc-46, Sb-125, Ba-140, and Eu-155 were routinely measured in air at Richland, WA, they were not detected in egg contents.

2597. Saifullah, S.M. 1978. Inhibitory effects of copper on marine dinoflagellates. Marine Biology 44:299-308.

Exposure of *Scrippsiella faeroense* to 0.020 mg Cu/l for 25 days decreased population size; 0.005 and 0.010 mg Cu/l reduced growth rates while 0.001 mg/l showed no effect. All levels of Cu decreased population size in semicontinuous cultures of *Scrippsiella* after 8 days. Populations of *Gymnodinium splendens* were decreased only in 0.020 mg Cu/l for 19 days; lesser concentrations showed no effect on growth. *Prorocentrum micans* populations decreased during exposure to 0.020 mg Cu/l for 21 days, exhibited reduced growth in 0.010 mg/l, and showed no response to 0.001 and 0.005 mg/l. Uptake of labelled carbon was reduced in *Scrippsiella* populations immersed in 0.010 or 0.020 mg Cu/l for 16 days; after an initial decline in 0.005 mg/l, uptake rate returned to normal by day 16. It was suggested that copper inhibits cell growth by arresting cell division, or by disrupting internal cell metabolism.

2598. Santerre, M.T. and R.C. May. 1977. Some effects of temperature and salinity on laboratory-reared eggs and larvae of Polydactylus sexfilis (Pisces:Polynemidae). Aquaculture 10:341-351.

Temperature and salinity effects on eggs and larvae of the marine teleost P. sexfilis were examined. Maximum larval length was observed between 23.8 and 28.6 C at 34 o/oo S. Normal development increased at 26 to 34 o/oo S at intermediate temperatures. Larvae reared in 34 o/oo S through yolksac had >50% survival between 21.9 and 28.0 C. Upper and lower salinity tolerances of 42-hr larvae were reduced at the two extreme temperatures, and were broadest at 26.2 C. Larvae 72 hrs old were more tolerant to high temperature than newly fertilized eggs. Authors recommended conditions of 24-28 C and 26-34 o/oo S for rearing P. sexfilis eggs.

2599. Sastry, K.V. and P.K. Gupta. 1978. Alterations in the activity of some digestive enzymes of Channa punctatus, exposed to lead nitrate. Bull. Environ. Contamin. Toxicol. 19:549-555.

After exposure for 15 days to 3.80 mg/l of lead nitrate, the freshwater fish, C. punctatus, exhibited decreases in alkaline phosphatase activity of intestine and pyloric caeca, but not liver and stomach; acid phosphatase was decreased in intestine and pyloric caeca, but not liver and stomach; trypsin increased in intestine and pyloric caeca; and pepsin increased in stomach. Fish exposed for 30 days to 3.80 mg Pb/l showed a decrease of alkaline phosphatase activity in pyloric caeca, an increase of acid phosphatase in all tissues, a greater increase of trypsin in both tissues analyzed, and an increase of pepsin in stomach. Among carbohydrase enzymes, amylase activity increased significantly in all tissues of fish exposed to 3.80 mg Pb/l for 15 days, maltase increased in all but liver, and lactase increased in liver, but lactase decreased in intestine and pyloric caeca. After 30 days exposure, amylase increased in liver, but decreased in stomach, intestine, and caeca; maltase decreased in caeca, and lactase increased only in stomach. Pattern of alteration in enzyme activities due to lead exposure is different in liver and digestive system.

2600. Shen, A.C.Y. and J.F. Leatherland. 1978. Effect of ambient salinity on ionic and osmotic regulation of eggs, larvae, and alevins of rainbow trout (Salmo gairdneri). Canadian Jour. Zoology 56:571-577.

Osmotic and ionic concentrations of eggs, larvae, and alevins of rainbow trout were measured in distilled water and dilute seawater of 11 and 13 o/oo S. Osmotic concentration, in mean depression of freezing point, was 0.05 in perivitelline fluid in distilled water, 0.43 in 11 o/oo S, and 0.49 in 13 o/oo S; only in distilled water was fluid osmotic pressure higher than ambient medium. Tissue water content decreased slightly in eggs from 65.5% to 63.6 and 63.9% in dilute seawater; water content in larvae dropped from 62.1% to 58.4 and 56.8% and in alevins from 66.9% to 60.6 and 57.8%. $Na^+:K^+$ ratio rose in eggs from 0.27 to 0.42 and 0.50 with an increase in salinity, remained steady in larvae at 0.26 to 0.28, and dropped in alevins from 0.55 to 0.29 and 0.25. Tissue Na^+ concentration increased significantly in eggs from 336 mg/kg wet wt in distilled water to 543 in 11 o/oo S and 614 in 13 o/oo S; larvae increased Na^+ only slightly, and in alevins decreased significantly from 570 to 419 and 391 mg/kg in dilute seawater. Tissue K concentrations increased slightly in eggs only in 11 o/oo S; larvae increased significantly from 2370 to 2428 and 2506 mg K/kg in seawaters, and alevins showed a slight increase. Over the 25 day period prior to hatching, egg Na levels rose from 299 to 529 mg/kg wet wt in distilled water, from 345 to 690 in 11 o/oo S, and from 391 to 805 mg Na/kg in 13 o/oo S. Authors suggest that early stages of trout possess limited osmotic or ionic regulation; larvae regulate tissue Na^+ by increasing Na^+ in perivitelline space and alevins tolerate an increase of tissue K^+ and decrease in tissue water content.

2601. Somero, G.N. and T.J. Chow. 1977. Lead effects on the estuarine teleost fish Gillichthys mirabilis: salinity and temperature effects on tissue-specific accumulation rates and lead effects on respiration rates. In: Giam, C.S. (ed.). Pollutant effects on marine organisms. D.C. Heath and Co., Lexington, MA: 36. (Abstract).

Lead accumulation in G. mirabilis occurred in tissue-specific patterns; spleen, gills, intestine, and fins accumulated maximum levels and muscle and liver the least. Lead-exposed fish that were returned to normal seawater lost lead in gills, intestine, and fins. Rapid Pb turnover in mucus-rich tissues may result from lead complexing to mucus, followed by sloughing of the mucus layers. Lead accumulation rates were directly proportional to temperature and inversely proportional to salinity. Oxygen consumption and excitability increased in fish exposed to Pb; gill tissue respiration did not change. Authors suggest that lead influences central nervous system functions in fish, especially neurotransmitter metabolism, as is the case with higher vertebrates.

2602. Sullivan, J.K. 1977. Effects of salinity and temperature on the acute toxicity of cadmium to the estuarine crab *Paragrapsus gaimardii* (Milne Edwards). Austral. Jour. Mar. Freshwater Res. 28:739-743.

LC-50 (96 hr) values for cadmium chloride on crabs, *P. gaimardii*, in static tests at 5 C rose from 22.4 to 101.9 mg/l as salinity increased from 8.6 to 34.6 o/oo. In 19 C, LC-50 (96 hr) values rose from 15.7 to 34.3 mg Cd/l as salinity increased. Mortality in crabs was greater at higher temperature and at lower salinity.

2603. Suzuki, Y., M. Nakahara, and R. Nakamura. 1978. Accumulation of cesium-137 by useful mollusca. Bull. Japan. Soc. Sci. Fish. 44:325-329.

Octopus, *Octopus vulgaris*, exposed to labeled cesium for 14 days, had Cs-137 activity ratios (cpm/g tissue : cpm/g SW) of 12.8 for liver, 10.9 for ovotestis, 8.0-8.3 for kidney, funnel, and branchial heart; 6.1 and 7.5 for heart, arms and tentacles, buccal bulb, ctenidia, and gastric caecum; 4.7-5.7 for stomach, sucker, oesophagus, and salivary gland; and 3.5 for mantle. Of the total body Cs-137, arms and tentacles contained 75%, mantle 11%, and other tissues <5.0%. Squid, *Doryteuthis bleekeri*, showed activity ratios after 6 days of 8.0 to 11.0 in arm, ctenidia, liver, and mantle, in decreasing order. Elimination of Cs-137 by *Octopus* tissues showed decreases from about 10,000 to 1000 cpm/g in arms over 75 days and to 500 in liver, ctenidia, and mantle. Biological half-life of cesium was 90 days. Elimination by the clam *Gomphina melanaegis* over 70 days showed decreases of 10,000-13,000 to 1000-1200 cmp Cs-137/g in muscle and viscera; biological half-life was 31 days. Concentration factors were similar among the classes of molluscs, which were close to values for crustaceans and slightly lower than Cs concentration factors for marine fish.

2604. Trefry, J.H. and B.J. Presley. 1976. Heavy metal transport from the Mississippi River to the Gulf of Mexico. *In*: Windom, H.L. and R.A. Duce (eds.). Marine pollutant transfer. D.C. Heath and Co., Lexington, MA:39-76.

Concentrations of Al, As, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb, and Zn in water and sediments of the lower Mississippi River and Gulf of Mexico are listed. Metal distributions in *Sargassum* and mixed phytoplankton from about 20 sites in the Mississippi Delta and Northwest Gulf were determined and ranged from 33 to 13,450 mg Al/kg dry wt, 2.9 to 82.0 for As, $<$0.05 to 46.0 for Cd, $<$0.5 to 6.6 for Co, 1.2 to 25.2 for Cu, 61 to 7550 for Fe, 2.5 to 39.2 for Pb, 4.5 to 181.0 for Mn, 0.9 to 15.6 for Ni, and 13.0 to 129.0 for Zn. Metal levels in zooplankton samples consisting of salps, coelenterates, ctenophores, chaetognaths, amphipods, copepods, decapods, euphausiids, ostracods, and fish larvae, ranged from 44.0 to 6000.0 mg Al/kg dry wt, 1.9 to 29.5 for As, 0.4 to 4.4 for Cd, $<$0.5 to 2.1 for Co, 3.5 to 74.0 for Cu, 62 to 4760 for Fe, $<$0.5 to 62.5 for Pb, 4.7 to 114.0 for Mn, $<$0.5 to 8.2 for Ni, and 41.0 to 200.0 for Zn. Authors concluded that there is little evidence of excessive metal levels in the lower Mississippi River. Although some phytoplankton samples contained elevated Pb and Cd content, overall concentrations are similar to unaffected areas. Sedimentary records showed increases in Pb and Cd, but not Co, Cr, Cu, Mn, Ni, or Zn from the Mississippi River.

2605. Ueda, T., R. Nakamura, and Y. Suzuki. 1978. Comparison of influences of sediments and sea water on accumulation of radionuclides by marine organisms. Jour. Radiation Res. 19:93-99.

Accumulations of ruthenium-rhodium and cesium by the clam *Gomphina melanaegis*, after exposure for 13 days to 0.2 mCi of radionuclides, is reported. A concentration factor (CF) of tissue over seawater of 4.0 in muscle, 1.5 in visceral organ, and 2.0 in edible parts was observed for Cs-137. For Ru-106-Rh-106, the CF was 8.0 in muscle and 6.0 in visceral organs and edible parts. For the alga *Cyrtymenia* sp., a CF after 11 days was about 3.0 for Cs-137 and 200 for Ru-106-Rh-106. Accumulation of radionuclides from sediments containing 0.2-1.0 mCi after 14 days was expressed as a transfer ratio (TR); this was 0.045 for Cs-137 and 0.0007 for Ru-106-Rh-106 in Gomphina, and 0.069 for Cs-137 and 0.054 for Ru-106-Rh-106 in Cyrtymenia. Biological factors of sediments (CF from seawater/TR from sediment) were 160 for Cs and 2900 for Ru-Rh in Gomphina and 70 for Cs and 5400 for Ru-Rh in Cyrtymenia; comparable values of seawater and sediment contamination were reported for the annelid Nereis japonica.

2606. Ui, J. and S. Kitamuri. 1971. Mercury in the Adriatic. Marine Poll. Bull. 2:56-58.

Total mercury in fish from six polluted sites in France and Italy ranged from 0.17 to 7.39 mg/kg dry wt; methyl mercury content ranged from 0.07 to 6.37 mg/kg dry wt. Factory effluent at Ravenna, site of maximum mean Hg levels in fish of 3.4 mg/kg total and 2.8 methylmercury, was 0.48 mg/l total Hg and 0.001 mg/l methylmercury. Fish from Nice, as a control, contained an average of 0.95 mg/kg dry wt total Hg and 0.34 methyl Hg. Mercury content in feathers of birds fed fish from one contaminated area was 17.4 mg/kg total Hg in gulls and 1.39 in chickens; methylmercury was 16.94 and 0.45 mg/kg, respectively. Hair from fishermen and their families in villages near polluted water ranged from 1.52 to 11.61 mg/kg total Hg and 0.34 to 5.53 mg/kg methyl Hg. Maximum levels were found near the Ravenna factory. People from Nice contained 1.58-7.39 mg/kg total and 0.75-7.16 methyl Hg in their hair.

2607. Windom, H. 1975. Heavy metal fluxes through salt-marsh estuaries. In: Cronin, L.E. (ed.). Estuarine research, vol. 1. Chemistry, biology, and the estuarine system. Academic Press, Inc., N.Y.: 137-152.

Flux of heavy metals through estuaries is controlled by adsorption-desorption reactions, flocculation, precipitation, and sedimentation, which occur at river-estuary and salt marsh-sediment boundaries. Some biological processes, such as uptake by vegetation, recycle metals from estuarine sediments. Mean metal concentrations in leaves and stalks of Spartina alterniflora along the southeastern Atlantic coast is 750 mg Fe/kg dry wt, 50 mg Mn/kg, 3.7 mg Cu/kg, 0.5 mg Cd/kg, and 0.2 mg Hg/kg. Average annual uptake by Spartina accounts for 3.0 to 17% of total imput of each metal into estuaries. Fates of dissolved and particulate fractions of Fe, Mn, Cu, Cd, and Hg in estuaries is discussed.

2608. Windom, H.L., W.S. Gardner, W.M. Dunstan, and G.A. Paffenhofer. 1976. Cadmium and mercury transfer in a coastal marine ecosystem. *In:* Windom, H.L. and R.A. Duce (eds.). Marine pollutant transfer. D.C. Heath and Co. Lexington, MA:135-157.

Transfer of cadmium and mercury from river discharge and atmosphere through the Georgia Embayment along the SE Atlantic coast is summarized. Average content of Georgia waters is 0.10 ug Cd/l and 0.06 ug Hg/l, with mean resident times of 2 yrs for Cd and 18 yrs for Hg. Sediments contained 1.6 mg Cd/kg dry wt and 0.07 mg Hg/kg dry wt. Among estuarine biota salt-marsh grass *Spartina alterniflora* contained 0.5 mg Cd/kg dry wt and 0.20 mg Hg/kg dry wt; crab *Uca* sp. 0.2 for Cd and 0.3 for Hg; and snail *Littorina* sp. 0.8 for Cd and 2.6 for Hg. As added Cd reached 10.0 ug/l, Cd concentration in the diatom *Skeletonema costatum* increased to 4.0 mg/kg dry wt. The copepod *Pseudodiaptomus coronatus*, included in the next higher trophic level, followed similar Cd uptake patterns. Mixed phytoplankton of *Carteria* sp., *Dunaliella tertiolecta*, and *Nitzchia closterium* accumulated up to 2.0 mg Hg/kg dry wt as water levels rose to 0.35 ug Hg/l. Cadmium concentrations in Atlantic croaker, *Micropogon undulatus*, a secondary consumer, increased to 0.23 mg/kg dry wt in stomach in 0.06 ug Cd/l, and to 0.27 ug/kg in gills in 0.6 ug Cd/l; liver and muscle levels were not elevated over controls. Cadmium and mercury transfer through an estuarine food chain was followed: 0.10 ug Cd/l and 0.06 ug Hg/l in seawater; 0.20 mg Cd/kg dry wt and 0.45 mg Hg/kg dry wt in phytoplankton; 0.15 and 0.15, respectively, for copepod primary consumers; 0.40 and 0.06 for shrimp, and 0.04-0.07 and 0.10-0.50, respectively, for fish secondary consumers; and 0.05-0.22 and 0.17-1.07, respectively, for fish tertiary consumers. Transfer efficiences for Georgia Embayment food chains were 0.20 Cd for primary consumer, 0.08-0.80 for secondary consumers, and 0.03-0.15 for tertiary consumer. For mercury, efficiencies were 0.08, 0.1-0.9, and 0.8-3.0 for respective trophic levels.

2609. Wu, L. and J. Antonovics. 1978. Zinc and copper tolerance of *Agrostis stolonifera* L. in tissue culture. Amer. Jour. Botany 65:268-271.

When grown on basic medium without additional copper and zinc, callus tissue from grasses *Agrostis stolonifera* tolerant to neither metal had a greater dry wt than calluses from tolerant plants. The Cu and Zn tolerant clones came from a copper refinery near Liverpool, England, where the soil was heavily contaminated with Zn (700 mg/kg) and Cu (4000 mg/kg). Grown on media containing 1.0 mg Cu/l or 12.0 mg Zn/l, tolerant individuals produced calluses 5X the weight of nontolerant ones. Metal uptake in culture resembled uptake by whole plants; tolerant tissues accumulated higher metal concentrations. Tolerant calluses contained up to 233 mg Cu/kg dry wt in 1.0 mg Cu/l and 2.0 mg Zn/l and up to 470 mg Zn/kg dry wt in 12.0 mg Zn/l and 0.01 mg Cu/l. Maximum metal concentrations in nontolerant calluses were 71 mg Zn/kg and 118 mg Cu/kg in respective media. Plants regenerated from calluses had the same Cu and Zn tolerance as parent clones regardless of time of growth in culture and origin of shoot or root. Results support previous evidence that metal tolerance is genetically determined and acts at the cellular level.

2610. Boyden, C.R., B.E. Brown, K.P. Lamb, R.F. Drucker, and S.J. Tuft. 1978. Trace elements in the Upper Fly River, Papau New Guinea. Freshwater Biology 8:189-205.

Concentrations of Ca, Mg, Cd, Co, Cu, Fe, Mn, Ni, Pb, and Zn were determined in waters, sediments, and biota at various sites in the Upper Fly River, New Guinea, between June and September, 1974. Concentrations of ions and soluble metals along the rivers ranged from 5500 to 42,300 ug/l for Ca, 700 to 1450 for Mg, 1 to 14 for Cu, 41 to 468 for Fe, <2 to 39 for Mn, <1 to 5 for Ni, <0.5 to 4.0 for Pb, and <0.4 to 9.5 for Zn. Maximum particulate associated metal concentrations were 10 ug/kg for Cu, 3840 for Fe, 110 for Mn, 2 for Mn, 2 for Ni, 2 for Pb, and 12 for Zn. Metal levels in the <200 um sediment fraction from the rivers were 2.2 to 5.5 mg/kg dry wt for Cd, 17 to 29 for Co, 17 to 851 for Cu, 32,600 to 97,100 for Fe, 380 to 1680 for Mn, 24 to 38 for Ni, 27 to 185 for Pb, and 82 to 274 for Zn. Soluble Cu levels from streams draining an area rich in copper ore were relatively low, due to the small amount of ore exposed to weathering, heavy rainfall, and high pH of water associated with limestone bedrock. More iron was transported in soluble form down the headwater tributary Alice River than in Fly River, but higher particulate Fe was found in the Fly. Concentrations of metals, in ug/kg dry wt, in river biota were as follows: in soft parts of the gastropod Melanoides sp. 5-10 for Cd, 82-164 for Cu, 1121-1425 for Fe, 374-521 for Mn, 8-18 for Ni, 26-29 for Pb, and 320-556 for Zn; in muscle and whole body of the crayfish Macrobrachium sp., 1.2-4.2 for Cd, 23-241 for Cu, 45-365 for Fe, 3-57 for Mn, 5-17 for Ni, 6-43 for Pb, and 58-175 for Zn; and in liver and muscle of fishes *Melanotaenia vanheurni*, *Nematocentris rubrostriatus*, *Neosilurus gjellerupi*, *Nedystoma dayi*, *Therapon* sp., *Parambassis gulliveri*, *Ambassis* sp., *Lates calcarifer*, *Zenarchopterus novaeguineae*, *Mogurnda mogurnda*, and *Lutjanus* sp., 0.6-9.4 for Cd, 1-62 for Cu, 10-5121 for Fe, 3-13 for Mn, 3-93 for Ni, 5-44 for Pb, and 36-612 for Zn. Metal levels in biota generally reflected background concentrations at each site. Concentrations of Cd, Cu, and Zn were lower in starved insects than unstarved individuals, but no consistent changes were observed for Fe or Mn.

2611. Cunningham, P.A. and D.S. Grosch. 1978. A comparative study of the effects of mercuric chloride and methyl mercury chloride on reproductive performance in the brine shrimp, *Artemia salina*. Environ. Pollution 15:83-99.

Exposure to 0.01 mg/l mercuric chloride produced a reduction in reproductive lifespan of *Artemia* from 54 days in controls to 27 days; male lifespan decreased from 56 days in controls to 34 days in 0.01 mg $HgCl_2$/l and female lifespan decreased from 53 to 20 days. Immersion in 0.001 and 0.005 mg $HgCl_2$/l had no significant effects on lifespan. Mean brood production dropped from 9.3 in controls to 6.2 in 0.001 mg $HgCl_2$/l and to 3.5 in 0.01 mg/l. When exposed to 0.005 and 0.01 mg/l methylmercuric chloride, *Artemia* had reduced reproductive lifespans of 11.4 and 2.3 days, respectively, compared to controls of 44 days. Also, male lifespan dropped from 44.8 days to 2.0-28.6 days in 0.01-0.002 mg CH_3HgCl/l, and female lifespan decreased from 44.0 to 7.9 and 2.7 days in 0.005 and 0.01 mg/l. Mean brood productions dropped significantly from 6.8 to 0.3-4.8 in 0.01-0.001 mg CH_3HgCl/l. Survival of nauplii produced by treated parents was not reduced at any mercuric chloride exposure tested, up to 0.01 mg Hg/l. Naupliar survival was reduced in several broods in 0.001 and 0.002 mg Hg/l as methylmercuric chloride. Pairs of adults exposed to >0.002 mg CH_3HgCl/l did not produce nauplii. Cysts produced by pairs exposed to all concentrations of $HgCl_2$ or 0.001 and 0.01 mg CH_3HgCl/l displayed 50% less viability and hatchability than controls. Methylmercuric chloride was more toxic to adult *Artemia* than mercuric chloride, affecting both production and offspring survival. Reciprocal cross experiments with methylmercury exposure suggest that females are more physiologically stressed than males in 0.001 and 0.002 mg CH_3HgCl/l.

2612. Finley, M.T. and R.C. Stendell. 1978. Survival and reproductive success of black ducks fed methyl mercury. Environ. Pollution 16:51-64.

A diet containing 3.0 mg Hg/kg was fed to black ducks, *Anas rubripes*, for periods of 28 weeks during two consecutive breeding seasons. Hens fed mercury had reduced hatchability of eggs, 44 to 52% compared to 57 to 72% for controls. Clutch size, egg production, and number of eggs incubated were also reduced compared to controls over both years. Breeder pairs fed mercury diets produced only 16 ducklings during two years, none of which survived more than one week; controls produced 73 ducklings. Mercury residues in eggs, embryos, and ducklings associated with contaminated diets averaged about 30% lower during the second breeding season than first year levels. Third eggs laid by treated hens contained a mean of 6.1 and 3.9 mg Hg/kg wet wt during the first and second years. Brains of dead ducklings contained mean values of 3.2 to 7.0 mg Hg/kg wet wt and showed lesions characteristic of mercury poisoning. Duckling muscle contained 5.4 to 6.2 mg Hg/kg, liver contained 10.2 to 14.5, and feather 40.8 to 65.6 mg Hg/kg wet wt. Mercury contents in tissues of adults fed mercury were 2.8 to 3.8 mg Hg/kg wet wt in brain, 4.0 to 4.5 in muscle, 11.2 to 16.0 in kidney, 21.3 to 23.1 in liver, and 56.1 to 65.7 in feathers. Mercury levels did not differ in males and females.

2613. Glandon, R.P. and C.D. McNabb. 1978. The uptake of boron by *Lemna minor*. Aquatic Botany 4:53-64.

Ambient boron was a determining factor in rate of boron accumulation in tissue of the freshwater plant, *L. minor*. After 6 days in 0.01 mg B/1, plants contained 0.01 mg B/kg dry wt; levels were 0.06 mg/kg in 0.11 mg B/1 and 0.09 mg/kg in 1.01 mg B/1. *L. minor* growing in a pond in Belding, Michigan, contained 988 to 3249 mg B/kg dry wt over the 1973 growing season. *Ceratophyllum demersum* from the same pond and collected at the same time accumulated 69 to 195 mg B/kg, or 10-45X less boron than *L. minor*.

2614. Kazmierczak, A., M. Adamska, and R. Gondko. 1978. The content of copper, iron, and proteins in the serum of decapoda occurring in Poland. Comp. Biochem. Physiol. 60A:11-12.

Copper and iron in hemolymph from 3 species of Polish freshwater crayfish were determined. Astacus astacus contained 44.0 mg/l total Cu, 2.3 mg/l free Cu, 41.4 mg/l bound Cu, and 1.4 mg bound Cu/g protein; A. leptodactylus contained 30.9 mg Cu/l, 2.5, 30.0, and 1.3 for respective Cu types; Orconectes limosus contained 55.9 mg Cu/l, 3.5, 53.5, and 1.4 for respective Cu types. Observed differences in total Cu concentrations were due to differences in protein concentrations between species. Iron content of A. astacus serum were 1.38 mg/l total and 1.33 free Fe; in A. leptodactylus there were 1.89 and 1.55, respectively; and in O. limosus 3.16 and 2.37, respectively. No bound iron was detected, indicating a lack of ferro-proteins in serum.

2615. Martin, J.-L.M., A. Van Wormhoudt, and H.J. Ceccaldi. 1977. Zinc-hemocyanin binding in the hemolymph of Carcinus maenas (Crustacea, Decapoda). Comp. Biochem. Physiol. 58A:193-195.

Hemolymph of the crab C. maenas contained 44.7 mg Cu/kg wet tissue and 32.2 mg Zn/kg. Ninety-three percent of the copper, or 41.6 mg/kg, was associated with hemocyanin; fibrin contained 2.1 mg Cu/kg and blood cells, lipids, and carotenoids contained 0.4 mg Cu/kg. All copper-binding proteins were hemocyanin. Sixty-eight percent of the zinc, or 22.0 mg/kg, was associated with hemocyanin; fibrin contained 2.3 mg Zn/kg and blood cells, lipids, and carotenoids contained 3.1 mg Zn/kg. Zn linked with hemocyanin was found on high molecular protein fractions only. Specific zinc-binding proteins were not found in serum of C. maenas.

2616. Melhuus, A., K.L. Seip, H.M. Seip, and S. Myklestad. 1978. A preliminary study of the use of benthic algae as biological indicators of heavy metal pollution in Sorfjorden, Norway. Environ. Pollution 15:101-107.

Mean concentrations of Zn, Cu, Pb, and Cd in seawater at 4 sampling sites in Sorfjorden, Norway, decreased from 313 to 113 ug Zn/l at sites closer to the mouth of the fjord, and generally decreased from 6.3 to 3.7 ug Cu/l, from 8.9 to 4.3 ug Pb/l, and from 2.2 to 0.81 ug Cd/l closer to the mouth. Range of levels in seawater were 8.0 to 900.0 ug Zn/l, 1.0 to 23.0 ug Cu/l, 1.0 to 92.0 ug Pb/l, and 0.5 to 9.0 ug Cd/l, with no trend according to sampling site. Mean zinc concentrations in algae Fucus vesiculosus, F. serratus, Ascophyllum nodosum, Chorda *filum*, and *Enteromorpha* sp. ranged from 950 to 7350 mg/kg dry wt. Concentration factors (CF) for *F. vesiculosus* and *A. nodosum* were 7100 to 24,000 over seawater at all sites. Mean levels of copper were 10.0 to 114.5 mg/kg dry wt with CF in 2 species ranging from 4800 to 20,000. Lead concentrations ranged from 10.4 to 163.4, with a high of 301.5 mg/kg dry wt; CF were 1200 to 26,000 in 2 species. Mean cadmium levels were 3.0 to 29.0 mg/kg dry wt; CF were 4200 to 13,000. CF's for Zn and Cd exhibited no trends with sampling location; however, Cu and Pb CF values decreased towards the mouth of the fjord.

2617. Murray, C.N. and R. Fukai. 1978. Measurement of $^{239+240}$Pu in the northwestern Mediterranean. Estuar. Coast. Mar. Sci. 6:145-151.

Measurements of Pu-239+240 were determined in seawater, sediments, and mussels from the NW Meditteranean Sea during 1973 and 1974. Levels ranged from 0.0005 to 0.0085 pCi/l for seawater from the surface to 2000 m depth, 0.3 to 4.2 pCi/kg dry wt for sediments along the shoreline and Rhone River, and 0.42 to 0.74 pCi/kg wet wt for whole body of mussels, *Mytilus galloprovincialis*, 0.19 pCi/l for pallial fluid, 0.18 pCi/kg for soft parts, and 0.61 for shells of mussels from the coastal area. Relatively higher plutonium concentrations were found in deep water, possibly correlated to vertical water movements characteristic of this portion of the Meditteranean.

2618. Murzina, T.A., I.P. Lubyanov, and A.M. Chaplina. 1976. Accumulation of Sr^{90} by freshwater plants in the Ukrainian steppe zone. Hydrobiological Jour. 12:66-70.

Fifteen species of freshwater plants from five reservoirs and ponds in the Ukrainian steppe zone concentrated strontium-90 over water by concentration factors (CF) ranging from 4.0 to 189.0 during spring, summer, and autumn of 1971 and 1972. CF of Sr-90 was related to species and ecological features of the plant. Accumulation values, in decreasing order, were submerged and rooted plants, submerged and rooted with leaves floating on the water surface, submerged and not rooted, and semisubmerged plants. Strontium-90 levels increased during the spring and summer, generally reaching maxima in July-August, then declined in autumn. CF in plants were dependent on salt composition of water and, in particular, Ca levels which ranged from 43 to 225 mg/l. Authors concluded that submerged plants *Potamogeton perfoliatus*, *Myriophyllum spicatum*, and especially *Chara* sp. may serve as biological indicators of strontium contamination.

2619. Panigrahi, A.K. and B.N. Misra. 1978. Toxicological effects of mercury on a freshwater fish, *Anabas scandens*, Cuv. & Val. and their ecological implications. Environ. Pollution 16:31-39.

Climbing perch, *Anabas scandens*, exposed to concentrations of 5.0 to 15.0 mg Hg/l as mercuric nitrate died within 24 hours. In 3 mg Hg/l, perch appeared lethargic and did not feed for 5 days, then regained pre-test activity by day 8; however, blindness and exophthalmia were noted in 24 of 35 fish between days 20 and 36. Respiration rate was reduced from 0.19 to 0.02 mg O_2/gm/hr after 21 days in 3.0 mg Hg/l, but fish recovered partially when transferred to fresh Hg-free water. After 45 days, treated fish accumulated 2.8 mg Hg/kg wet wt in muscle and 3.0 in liver; control fish contained <0.002 mg Hg/kg in both tissues. Haemoglobin percentage, red blood cell count, body wt, and protein content of Hg-exposed fish were reduced considerably when compared to controls. Physiological and biochemical disorders were related to mercury concentrations in tissue. Algae accumulated 0.76 mg Hg/kg wet wt and *Hydrilla* plants 0.83 mg/kg wet wt during exposure for 45 days in 0.3 mg Hg/l.

2620. Ryndina, D.D. 1976. Accumulation and fixation of radionuclides by algal polysaccharides. Hydrobiological Jour. 12:33-37.

Sorption and desorption of nuclides of calcium, cesium, cobalt, iron, manganese, strontium, yttrium, and zinc by polysaccharides, alginic acid, cellulose-algulose, and barium complex of fucoidan, was measured in marine brown algae *Cystoseira*, *Padina*, *Laminaria*, and *Phyllophora* collected from several Ukrainian bays. Algulose accumulated Ce-144 by a factor of 2740, Co-57 to 990, Y-91 to 9960, and Zn-65 to 9960 from the environment. Algulose from fresh *C. barbata* concentrated Ce-144, Co-57, Fe-55, Mn-54, and Zn-65 to a greater extent than samples from decomposing organisms, apparently owing to polysaccharide structural changes during detritus formation. Alginic acids from *Cystoseira* concentrated Ce-144 by 3360X, Fe-55 to 350, Sr-90 to 440, and Y-91 to 300. Accumulation coefficients of the barium complex of fucoidan in *Cystoseira* reached 31,410 for Ce-144, 9710 for Co-57, 6340 for Mn-54, 2320 for Y-91, and 12,220 for Zn-65. High sorption properties make Ce-144, Co-57, and Y-91 extraction from the environment very efficient. Stability of fixation was high for Y-91 with all three polysaccharides; desorption at equilibrium was only 0.6 to 12.0%, with a high of 37.2%. Desorption of Zn-65 from algulose was 24 to 47%, Mn-54 from barium fucoidan was 44 to 45%, and Fe-56 from algulose was 12 to 57%, with a high of 90%. Other radionuclides generally did not form stable bonds with polysaccharides.

2621. Sarkka, J., M.-L. Hattula, J. Janatuinen, and J. Paasivirta. 1978. Mercury and chlorinated hydrocarbons in plankton of Lake Paijanne, Finland. Environ. Pollution 16:41-49.

Total mercury content in plankton composed mainly of copepods and other small crustaceans, rotifers, and algae during 1972-1974 ranged between 23 and 718 ug Hg/kg dry wt, with a mean of 178 ug/kg. Differences in mercury content due to time of year or size fraction of plankton sample were not significant. Mercury levels were generally of the same order as marine plankton, but lower than polluted regions elsewhere. Concentrations of polychlorinated biphenyls and DDE and DDT were also determined.

2622. Sharpe, M.A., A.S.W. deFreitas, and A.E. McKinnon. 1977. The effect of body size on methylmercury clearance by goldfish (Carassius auratus). Environ. Biol. Fishes 2:177-183.

Whole body retention of methylmercury ingested by goldfish, ranging in body weight from 1.0 to 50 g, was measured by adding tracer amounts of labelled CH_3HgCl to a single ration of food. Mean amount of methylmercury ingested ranged from 0.9 to 12.9 mg/fish, with amount deposited in body tissue extending from 0.7 to 11.0 mg CH_3Hg/fish. Body methylmercury was cleared faster in smaller fish per unit weight, with a biological half-life of 53 days for 5 gm fish compared to 160 days for 43 gm fish. Whole body clearance was a first order process in which mercury acted as a single homogeneous compartment described by: $R_{pcl} = k_{cl}PW^{-0.58}$, where R_{pcl} is elimination rate from body (ug/day); k_{cl} = elimination constant for 1 gm fish, is 0.029/day; P is methylmercury body content (ug); and W weight of fish (gm). Results suggest metabolic rate could be a factor in controlling clearance rate;

however, no temperature effect was seen in fish of similar weight maintained at 5, 10, and 15 C. Authors propose that allometric disproportions in demethylation or other clearance related functions may control methylmercury clearance, rather than metabolic rate.

2623. Singh, K. 1978. Serum iron level of the common Indian frog *Rana tigrina* Daud. Experientia 34:433-434.

Frog serum iron concentration was determined monthly over 2 years and ranged from 846 to 1129 ug Fe/l in females and 779 to 1030 ug/l in males; levels averaged 994 ug Fe/l in females and 926 in males over this period. Serum iron concentrations were relatively high from May to October in both sexes. Frogs showed decreased serum iron from day 16 onwards during starvation, losing about 110 to 180 ug Fe/l after 28 days.

2624. Spehar, R.L., R.L. Anderson, and J.T. Fiandt. 1978. Toxicity and bioaccumulation of cadmium and lead in aquatic invertebrates. Environ. Pollution 15:195-208.

Toxicity of cadmium and lead to freshwater insects *Pteronarcys dorsata*, *Hydropsyche betteni*, *Brachycentrus* sp., and *Ephemerella* sp., a gastropod *Physa integra*, and amphipod *Gammarus pseudolimnaeus* were determined during 28-day exposures. Survival of snails decreased significantly to 40% at 85.5 ug Cd/l after 7 days; after 21 days, survival decreased to 35% in 27.5 ug Cd/l; survival in controls, 3.0, and 8.3 ug Cd/l were the same. LC-50 values for snails exposed to cadmium were about 100 ug/l after 7 days, 50 ug/l after 14 days, and 10 ug/l after 28 days. Survival of *Gammarus* in cadmium was 62% (238 ug Cd/l) to 95% (<0.05 ug Cd/l); by day 28, survival was ≤25% in all concentrations except those 0.005 mg Cd/l. Cadmium concentrations in insects exposed for 28 days rose from 0.0-10.0 mg/kg dry wt to >100 mg/kg as water levels increased from 1.0 to 238 ug Cd/l, reaching concentration factors of 30,000. Survival of *Gammarus* dropped below 10% by 7 days in 136 to 565 ug Pb/l; after 21 days survival was 50% in 67 ug Pb/l and comparable to controls in 32 ug Pb/l. LC-50 values for *Gammarus* were about 125 ug Pb/l after 4 days, 70 ug/l after 7 days, 60 ug/l after 14 days, and 20 ug/l after 28 days. Lead concentrations up to 565 ug/l did not cause significant decreases in survival of snails or insects *Pteronarcys* and *Hydropsyche*. Insects accumulated up to 1000 mg Pb/kg dry wt after 28 days exposure to 565 ug Pb/l; concentration factors were up to 9000 over water. Lowest effect concentrations after 28 days were 3.0 ug Cd/l for Ephemerella, 27.5 ug Cd/l for Physa, and 32 ug Pb/l for Gammarus; these values were similar to those affecting fish exposed over their complete life cycle. Lethal threshold levels for insects were not observed for either metal, indicating possible effects could occur at lower concentrations during longer exposures.

2625. Stern, S. and Y. Achituv. 1978. Effects of temperature and salinity on the metabolism and byssal formation of Brachidontes variabilis Krauss (Bivalvia). Comp. Biochem. Physiol. 59A:101-105.

When mussels, B. variabilis, were transferred from water of 42 o/oo S to 47 or 58 o/oo S, oxygen uptake dropped to 2.0 ml O_2/g dry wt/hr in one day and leveled off through day 18; this stabilization indicated adaptation. Combined increases in salinity and temperature resulted in initial fluctuations in O_2 uptake followed by a return to control levels. Nitrogen excretion increased steadily from 50 ug N/g dry wt/hr to 175 over 20 days during exposure to higher salinity, suggesting enhanced protein utilization. Partial recovery of byssal formation was observed at test salinities. At 47 o/oo S, 25% of byssal formation was attained within 24 hrs, and 50% several days later. Byssal formation was 75% attachment after 5 days at 58 o/oo S. Degree of stress on animals was positively correlated to percentage of animals forming byssus. For the 100 day period, no mortality was observed at either salinity. Metabolic plasticity of B. variabilis is believed to play a major role in its migration from the Red Sea into the Mediterranean.

2626. Stobbart, R.H., J. Keating, and R. Earl. 1978. A study of sodium uptake by the water flea Daphnia magna. Comp. Biochem. Physiol. 58A:299-309.

The sodium transport mechanism of the freshwater cladoceran D. magna is initiated by a Na deficiency of approximately 230 mg/kg wet wt. It is inhibited by KCN and 2-4 dinitrophenol, and exhibits saturation kinetics with respect to external Na concentrations. Water fleas were depleted of Na when placed in 20.0 mg Ca^{2+}/l for 24 hrs. Na-depleted animals absorb Na from the external medium and regain their normal Na content of about 600 mg/kg wet wt after 15 hrs in water with 18.4 mg Na^+ and 40 mg Ca^{2+}/l. Influx, outflux, and net uptake all declined exponentially at the same rate during net Na uptake. An effective negative feedback appeared to operate continually on the Na transport mechanism, which generated carrier-mediated exchange and resembled those of freshwater mosquito and chironomid larvae.

2627. Sullivan, J.F., B.R. Murphy, G.J. Atchison, and A.W. McIntosh. 1978. Time dependent cadmium uptake by fathead minnows (*Pimephales promelas*) during field and laboratory exposure. Hydrobiologia 57:65-68.

Minnows exposed to 2.5 ug Cd/l in an industrially polluted lake accumulated 3.19 mg Cd/kg whole body dry wt in 12 hrs; pretest level was 0.29 mg Cd/kg. Minnows, averaging 0.002 mg Cd/kg whole body, exposed to 48 ug Cd/l as $CdCl_2$ in a continuous flow laboratory system contained 0.5 mg Cd/kg dry wt after 10 hrs, and did not reach comparable field levels until 8 days, at 3.57 mg Cd/kg. Whole body Cd in laboratory exposures peaked at 8.26 to 10.70 mg/kg within 17-20 days. Authors suggest that the more rapid uptake of cadmium by fish in the field may be due to additional physiological stress of other pollutants or interactions between pollutants, increased water turbidity and temperature which increases fish ventilation and metabolism, and decreased hardness which increases the percentage of total metal in ionic form and therefore available for biological accumulation.

2628. Weis, P. and J.S. Weis. 1978. Methylmercury inhibition of fin regeneration in fishes and its interaction with salinity and cadmium. Estuar. Coast. Marine Sci. 6:327-334.

Regeneration of amputated caudal fins in mullets, *Mugil cephalus*, was retarded by exposure to methylmercuric chloride in diluted seawater of 9 o/oo S. By 13 days, regenerated fin length was 3.0 mm in controls, 2.7 mm in fish from 0.001 mg CH_3HgCl/l, and 2.4 in 0.01 mg CH_3HgCl/l. The response was correlated with whole body uptake of mercury; mullets contained $<$0.1 mg Hg/kg in control water, 0.3 mg/kg in 0.001 mg CH_3Hg/l, and 5.0 mg/kg in 0.01 mg/l. Fin regeneration after 14 days in killifish, *Fundulus*, reached 3.3-3.4 mm in 36 o/oo S and only 2.4-2.7 in 9 o/oo S. Addition of 0.01 and 0.05 mg CH_3Hg/l reduced regeneration rates to 2.9 and 2.4 mm, respectively, in full strength SW; no significant decrease was observed in diluted SW with methylmercury, in which growth rate was already depressed. Mean fin regeneration in

Fundulus in 36 o/oo S was 2.6-3.2 mm in 0.025 mg CH_3HgCl/l and 2.9-3.4 in 0.025 mg $CdCl_2$/l at day 14, compared to 3.2-3.6 in controls. Mixtures of 0.005 or 0.025 mg Cd/l with 0.005 or 0.025 mg Hg/l counteracted growth inhibition of methylmercury, so that fish exhibited fin growth rates similar to controls over 14 days exposure.

2629. Wentsel, R., A. McIntosh, and G. Atchison. 1977.
Sublethal effects of heavy metal contaminated sediment on midge larvae (_Chironomus tentans_).
Hydrobiologia 56:153-156.

Insect larvae were maintained for 17 days in lake sediments of loam or silt-loam containing various levels of Cd, Cr, and Zn. Survival was 82% in control sediment containing 0.6 mg Cd/kg dry wt, 17.0 mg Cr/kg, and 77.0 mg Zn/kg; 70% survived in sediments of 420 mg Cd/kg dry wt, 1510 mg Cr/kg, and 8330 mg Zn/kg; 53% survived in 210 mg Cd/kg, 800 mg Cr/kg, and 4390 mg Zn/kg; 50% survived in 960 mg Cd/kg, 2130 mg Cr/kg, and 16,400 mg Zn/kg; and 47% survived in 1030 mg Cd/kg, 1640 mg Cr/kg, and 17,300 mg Zn/kg. Mean length and weight of larvae from control sediment were 1.83 cm and 2.86 mg; smallest larvae were found in sediments with 960 mg Cd/kg dry wt, 2130 mg Cr/kg, and 16,400 mg Zn/kg, with mean length of 0.82 cm and weight of 0.20 gm. A linear relationship was found for the square root of length _vs_. sediment metal levels.

2630. Wentsel, R., A. McIntosh, and W.P. McCafferty. 1978.
Emergence of the midge _Chironomus tentans_ when exposed to heavy metal contaminated sediment.
Hydrobiologia 57:195-196.

In test chambers with uncontaminated sediment containing 0.6 mg Cd/kg dry wt, 17.0 mg Cr/kg, and 77.0 mg Zn/kg, a mean of 14.2 adult chironomids, _C. tentans_, emerged from larval stages over 14 days following the first emergence. When exposed to sediments containing 1030 mg Cd/kg dry wt, 1640 mg Cr/kg, and 17,300 mg Zn/kg, an average of only 4.3 adults emerged. Number of emergences per day peaked at 8 to 16 over the trial period in controls, maximum emergences were 4 to 7 per day in contaminated sediments, with a delay of 2 days before adult emergence. Authors concluded that test sediments caused a decline and delay in emergence of chironomids by stressing or killing the insects.

2631. Whitaker, J., J. Barica, H. Kling, and M. Buckley. 1978. Efficacy of copper sulphate in the suppression of *Aphanizomenon flos-aquae* blooms in prarie lakes. *Environ. Pollution* 15:185-194.

Five shallow eutrophic prarie lakes in the Erickson-Elphinstone area of Manitoba, Canada, were treated with copper sulphate to control *A. flos-aquae* algal blooms and prevent summer fish kills. Concentrations of 25 to 360 ug Cu/l were added to lakes and 100 to 3000 ug Cu/l to experimental tubes in early July when algal filaments were about 10 mm in length. Chlorophyll *a* concentrations were 48 to 55 ug/l and bloom compositions were 90 to 98% *A. flos-aquae* before treatment. Algal control was achieved at all test concentrations. In general, chlorophyll *a* declined to 2.0 to 4.0 ug/l after 4 days and *A. flos-aquae* completely disappeared. Algal biomass remained low for 2 to 3 wks before gradually increasing. Chlorophytes, diatoms, and chryophytes usually dominated the algal community for the remainder of the ice-free season. In two other lakes, however, cyanophytes *Microcystis* spp. were predominant. Concentrations between 25 and 40 ug Cu/l, below recommended levels by provincial agricultural departments, were effective in *Microcystis*-dominated lakes. Copper concentrations in water returned to background levels in 8 to 10 days. Single applications $<$40 ug Cu/l are below toxic concentrations for rainbow trout; therefore, Cu fish kills will not occur, and Cu will not concentrate in fish stock.

2632. Whittle, K.J., R. Hardy, A.V. Holden, R. Johnston, and R.J. Pentreath. 1977. Occurrence and fate of organic and inorganic contaminants in marine animals. *In:* Kraybill, H.F., C.J. Dawe, J.C. Harshbarger, and R.G. Tardiff (eds.). Aquatic pollutants and biologic effects with emphasis on neoplasia. Annals New York Acad. Sci. 298:47-79.

Concentrations of contaminants in marine systems including hydrocarbons, organochlorine and organophosphorus pesticides, other organic compounds, heavy metals, and radionuclides are reviewed. Estimates of mean seawater concentrations of important heavy metals are 2.3 to 2.6 ug/l arsenic, 0.05 to 0.1 cadmium, 0.5 to 0.6 chromium, 3.0 copper, 0.03 lead, 2.0 manganese, 0.05 to 2.0 for mercury, 2.0 to 7.0 nickel, 0.09 to 0.45 selenium, 0.1 to 0.3 silver, and 5.0 to 10.0 zinc. Mean values from the literature for Hg, Pb, Cd, Cr, and As in some commercially important marine animals are: fishes (flounder, cod, haddock, hake, pollock, tuna) 0.07 to 0.51 mg Hg/kg wet wt, 0.28 to 1.64 for Pb, 0.03 to 0.26 for Cd, 0.08 to 0.11 for Cr, and 2.14 to 2.56 for As; molluscs (clams, oysters) 0.08 to 0.10 mg Hg/kg wet wt, 1.60 to 24.9 for Pb, 0.22 to 1.88 for Cd, 0.12 to 0.33 for Cr, and 3.13 to 9.12 for As; and crustaceans (blue crab, brown shrimp) 0.16 to 0.70 mg Hg/kg wet wt, 0.46 to 0.54 for Pb, 0.09 to 3.62 for Cd, 0.07 to 0.14 for Cr, and 8.71 to 12.16 for As. Dose rates of radionuclides, including Cs-137, Pu-239, and Sr-90, to phytoplankton, zooplankton, molluscs, crustaceans, and fish from various environmental sources are also listed.

2633. Wittig, K.P. and S.C. Brown. 1977. Sodium balance in the newt, *Notophthalmus viridescens*. Comp. Biochem. Physiol. 58A:49-52.

Sodium fluxes of *N. viridescens* were higher than those of any amphibian previously examined. Total sodium loss from unfed newts was 1136 mg/kg/day, about 102% of total body Na/day. Integumental loss accounted for 68% of the total, and urinary loss the remainder. Integumental Na uptake exhibited saturation kinetics. Maximum rate of transport was 5380 mg/kg/day; indicating only a weak affinity for Na. The high capacity of the transport system allowed losses to be replaced at external sodium concentrations approaching 2.3 mg/l.

2634. Yamamoto, Y., T. Ishii, M. Sato, and S. Ikeda. 1977. Effect of dietary ascorbic acid on the accumulation of copper in carp. Bull. Japan. Soc. Sci. Fish. 43:989-993.

Dietary L-ascorbic acid (AsA) decreased the rate of copper accumulation in carp, *Cyprinus carpio*, exposed to 0.05 mg Cu/l as $CuSO_4$ for 9 weeks. Control fish contained 1.0 to 2.5 mg Cu/kg wet wt in gills and 5.0 to 15.0 mg Cu/kg in hepatopancreas after 9 weeks regardless of AsA in diet. Carp exposed to Cu and fed AsA contained 3.5 mg Cu/kg wet wt in gill by 9 weeks and 25.0 mg/kg in hepatopancreas; exposed carp with no AsA contained 4.5 mg Cu/kg dry wt in gill and accumulated up to 55.0 mg/kg in hepatopancreas. Copper contents in other tissues were also maximum in carp exposed to Cu without AsA: kidney contained 4.0 mg/kg wet wt, intestine 8.1, vertebra 2.7, and serum contained 2.7 mg Cu/l after 9 weeks. Accumulation of copper reduced hepatopancreas AsA levels to 125 and 60 mg/kg wet wt in exposed fish with and without dietary AsA, respectively. Controls contained about 250 mg AsA/kg. Hepatic L-gulonolactone oxidase activity was also reduced in carp maintained in 5.0 mg Cu/l. Body weight in control fish increased from 85 to 125 gm over 9 weeks, while Cu-exposed carps weighed 80-85 gm after this period; presence of dietary AsA made no difference to either group. Authors concluded that AsA prevented copper accumulation and that accumulated Cu decreased AsA level in hepatopancreas by inhibiting biosythesis of AsA in carp.

2635. Anon. 1978. Selected pollution profiles: North Atlantic, North Sea, Baltic Sea, and Mediterranean Sea. Ambio 7:75-78.

Data from the International Council for the Exploration of the Seas (ICES) monitoring programs between 1972 and 1976 for mercury, DDT and polychlorinated biphenyls in the Baltic and North Seas and North Atlantic were summarized and compared with data from the Mediterranean. Mercury levels ranged from <0.02 to 0.09 mg/kg wet wt for mussels and 0.04 to 0.18 mg/kg for shrimp in the North Sea, with no significant difference between years. Deep sea prawns from the North Atlantic all had low levels of <0.03 mg Hg/kg; no appraisal was made from the Baltic Sea because only small numbers of bivalves were analyzed during this period. Codfish muscle contained mean mercury levels of 0.02 to 0.48 mg/kg over the 6 years in the North Sea; concentrations ranged from 0.02 to 0.88 mg Hg/kg in the Baltic Sea with the highest value from Oresund. In the North Atlantic, mercury concentrations ranged from 0.01 to 0.09 mg/kg wet wt in cod liver and 0.02 to 0.32 in muscle; lowest muscle levels were from Greenland and highest from the Irish Sea. In general, fish from the Mediterranean had higher concentrations, from 0.15 to 0.40 mg Hg/kg, than mussels, but the same as squid and octopus. Hg levels 2-3X higher than fish from the Atlantic and above official "safe" standards used by most Mediterranean countries were found in tuna and swordfish, reaching 2.5 to 3.5 mg/kg wet wt in tuna.

2636. Austin, B., D.A. Allen, A.L. Mills, and R.R. Colwell. 1977. Numerical taxonomy of heavy metal-tolerant bacteria isolated from an estuary. Canadian Jour. Microbiol. 23:1433-1447.

A total of 230 strains of metal-tolerant bacteria from Chesapeake Bay and Colgate Creek, where environmental levels were

52 mg Co/l, 18 mg Pb/l, 39 mg Hg/l, and 8.0 mg Mo/l in water and 0.0 mg Co/kg, 26-38 mg Pb/kg, 8.0-13.0 mg Hg/kg, and 4.0-24.0 mg Mo/kg in sediments, were isolated on a medium containing 100 mg Co/l, 100 mg Pb/l, 10 mg Hg/l, and 100 mg Mo/l. Biochemical, cultural, morphological, and physiological characters were analyzed; simple matching and Jaccard coefficients were calculated from the taxonomic data. Bacillus, Erivinia, Mycobacterium, Pseudomonas, and coryneforms were identified from the strains. It was concluded that metal tolerance in estuarine water and sediment bacteria occurs among a restricted range of taxa distributed throughout the estuarine environment.

2637. Bradley, B.P. 1975. The anomalous influence of salinity on temperature tolerances of summer and winter populations of the copepod Eurytemora affinis. Biol. Bull. 148:26-34.

Times to succumb (TS) and time to recover (TR) from temperature shock, by raising or lowering temperature one degree every five minutes, were measured in copepods acclimated for 24 hrs at 4 salinities. Temperature tolerance limits were determined as the temperature at which half the test animals became inactive. Copepods collected in March, when environmental salinity was 6 o/oo S, had TS values from 3 minutes in 3 o/oo S up to 5 minutes in 15 o/oo S; TR values ranged from 19 min in 3 o/oo S to 3 min in 15 o/oo S. TS values for copepods collected in August, when salinity was <1 o/oo S, were from 4 min in 3 o/oo S up to 13 min in 15 o/oo S; TR values ranged from 13 min in 3 o/oo S to <2 min in 15 o/oo S. TS and TR values were significantly different between populations and between salinities of 3, 9, 12, and 15 o/oo S. Without prior acclimation to test salinities, TS values for copepods collected in March were 2.9 min in 0.0-1.0 o/oo S and 3.4 min in 12 o/oo S; TR values were 20 min and 12 min, respectively. TS values for copepods collected in August were 3 min in 0.0-1.0 o/oo S and 5 min in 12 o/oo S; the TR values were 13 and 10 minutes.

2638. Cardwell, R.D., D.G. Foreman, T.R. Payne, and D.J. Wilbur. 1976. Acute toxicity of selenium dioxide to freshwater fishes. Arch. Environ. Contamin. Toxicol. 4:129-144.

Decreasing order of species sensitivity to selenium dioxide was determined as: fathead minnow Pimephales promelas, flagfish Jordanella floridae, brook trout Salvelinus fontinalis, channel catfish Ictalurus punctatus, goldfish Carassius auratus, and bluegill Lepomis macrochirus. LC-50 values for juvenile minnows were 31.2 mg Se/l (18.5 hr), 7.3 mg/l (96 hr), and 2.9 mg/l (168 and 220 hr); for adult trout these values ranged from 87.3 mg Se/l (6 hr) to 14.3 mg/l (96 hr); for juvenile catfish LC-50 values extended from 46.7 mg Se/l (23 hr) to 19.1 mg/l (94 hr); for juvenile goldfish these were 110.0 mg Se/l (12 hr), 36.6 mg/l (96 hr), and 8.8 mg/l (336 hr); for juvenile bluegill LC-50 values ranged from 126.6 mg Se/l (8 hr) to 17.6 mg/l (336 hr); and for juvenile flagfish LC-50 values ranged from 37.6 mg Se/l (44 hr) to 11.2 mg/l (83 hr). Minnow and flagfish juveniles exposed to Se for 24 hr showed a limited delayed mortality but no effect on growth over a 28 day period.

2639. Casterline, J.L., Jr., and G. Yip. 1975. The distribution and binding of cadmium in oyster, soybean, and rat liver and kidney. Arch. Environ. Contamin. Toxicol. 3:319-329.

Tissue of oysters grown for 6 days in water with 0.1 mg $CdCl_2$/l contained 2.66 mg Cd/kg in the combined cell fraction of nuclei, mitochondria, and microsomes, with 24.4 mg Cd/kg in total homogenate and 21.4 mg/l in total supernatant. Cadmium was principally bound to proteins of 9,200 to 13,800 molecular wt. Significant amounts were also associated with fractions 3,000 and 50,000. Distribution of cadmium after exposure to Cd and/or Cd-109 was also determined in soybeans and rat liver and kidneys.

2640. Dieter, M.P., M.C. Perry, and B.M. Mulhern. 1976. Lead and PCB's in canvasback ducks: relationship between enzyme levels and residues in blood. Arch. Environ. Contamin. Toxicol. 5:1-13.

Blood samples from ducks Aythya valisineria collected from Chesapeake Bay in winter of 1974 were analyzed for lead and organochloride contamination. Delta-aminolevulinic acid dehydrogenase (ALAD) activity in blood provided an estimate of Pb contamination in waterfowl. Ducks containing normal blood levels of lead, that is 59-64 ug Pb/l, had ALAD activities of 98-110 units, with no difference between sexes. Sixteen of 95 ducks showed >50% enzyme inhibition with a mean activity of 28 units with blood lead concentrations of 263 ug/l, 4X normal. Ducks containing 525 to 630 ug Pb/l in blood had enzyme activities of <25 units. Lead was a more prevalent environmental contaminant than organochloride compounds in ducks; 17% of the blood samples had <50% ALAD activity due to Pb contamination, but only 11% exhibited abnormal activities of two other enzymes known to respond to organochloride poisoning.

2641. Dillon, T.M. 1977. Mercury and the estuarine marsh clam, Rangia cuneata Gray. I. toxicity. Arch. Environ. Contamin. Toxicol. 6:249-255.

LC-50 (96 hr) values for clams exposed to mercuric chloride were 0.122 mg Hg/l when clams were acclimated in 2 o/oo S, and 0.058 mg/kg in 15 o/oo S. The LC-50 (72 hr) values were 0.242 mg Hg/l in 2 o/oo S, and 0.057 in 15 o/oo S. Clams acclimated to 0.008 mg Hg/l for 2 weeks, followed by 9 days in mercury-free seawater, survived longer during exposure to 0.87 mg Hg/l than non-acclimated clams. At 170 hrs, 75% of non-acclimated clams were dead; at 220 hrs, only 55% of acclimated clams had succumbed. At 168 hours dead non-acclimated specimens contained 12 mg Hg/kg wet wt, and dead acclimated clams 32 mg Hg/kg.

2642. Eganhouse, R.P. and D.R. Young. 1978. Total and organic mercury in benthic organisms near a major submarine wastewater outfall system. Bull. Environ. Contamin. Toxicol. 19:758-766.

Mercury levels were measured in marine benthic animals to determine whether sediment concentrations of 0.14 to 5.50 mg Hg/kg dry wt and wastewater particulate concentrations of 4.0 to 5.0 mg Hg/kg dry wt, off Palos Verdes Peninsula, California, were reflected in local biota. Median mercury levels in ug/kg wet wt, in Dover sole Microstomus pacificus from Palos Verdes were 52 in muscle, 99 in liver, 41 in kidney, and 24 in gill; Hg content in Dover sole from Catalina Island, a control site, was generally higher at 157 in muscle, 141 in liver, 30 in kidney, and 19 in gills. Crabs Mursia gaudichaudii from Palos Verdes contained 18 ug Hg/kg wet wt in muscle and 33 ug/kg in digestive gland; specimens from Catalina Island contained 158 and 81, respectively. Muscle of prawns Sycionia ingentis contained 38 ug Hg/kg wet wt from Palos Verdes and 49 from Catalina; gonads of urchins Allocentrotus fragilis contained 20 ug Hg/kg wet wt from Palos Verdes and 34 from Catalina; and whole body of sea slugs Pleurobranchaea california contained 16 ug Hg/kg wet wt from Palos Verdes and 11 from Catalina. Instead of showing enhanced uptake and accumulation, outfall organisms generally had similar and sometimes depressed tissue concentrations of mercury. Mean organic mercury concentrations, in ug/kg wet wt, in animals collected off Palos Verdes Peninsula were for sole, 41 in muscle, 9 in liver, and 10 in gills; for crabs, 17 in muscle and 5 in digestive glands; for prawns, 29 in muscle; for urchins, 3.0 in gonads; for sea slugs, 7.0 in whole body; and for snails *Callinaticina oldroydi*, 16 in viscera. Average percent organic mercury ranged from 9.6% in liver from sole to 87.1% in crab muscle.

2643. Frank, R., M.V.H. Holdrinet, and W.A. Rapley. 1975. Residue of organochlorine compounds and mercury in birds' eggs from the Niagara Peninsula, Ontario. Arch. Environ. Contamin. Toxicol. 3:205-218.

Eggs from 20 species of birds from both terrestrial and aquatic food chains, were collected from the Niagara Peninsula, Ontario, Canada, in 1971, and analyzed for total mercury, organochlorine insecticides, and polychlorinated biphenyls. Among marsh and aquatic feeders, the herbivorous-insectivorous red-winged blackbird *Agelaius phoeniceus*, Canada goose *Branta canadensis*, and mallard *Anas platyrhynchos* contained mean mercury levels of 0.68, 0.12, and 0.15 mg/kg, respectively, in whole eggs. Mean mercury concentrations in eggs from the aquatic carnivores herring gull *Larus argentatus*, black-crowned night heron *Nycticorax nycticorax*, and common tern *Sterna hirundo*, were 0.74, 0.64, and 0.83 mg Hg/kg. Eggs of carnivorous species at the top of the aquatic food chain had the highest mean mercury residues. Eggs of terrestrial carnivores contained 0.06 to 0.09 mg Hg/kg, eggs of omnivores contained 0.12 mg Hg/kg, and herbivores-insectivores contained 0 06 to 0.07, with a high of 0.18 in starling eggs.

2644. Giddings, J.M. and G.K. Eddlemon. 1977. The effects of microcosm size and substrate type on aquatic microcosm behavior and arsenic transport. Arch. Environ. Contamin. Toxicol. 6:491-505.

The fate of 0.05 mg As/l, labelled with $H_3As\text{-}^{74}O_4$, was studied in 12 freshwater microcosms of two sizes and substrates. Most of the arsenic moved into mud of lake sediment microcosms within 2 weeks, but remained in water in sand microcosms. Water in large (70 l) aquaria with lake sediment contained 0.007-0.012 mg As/l and in small (7 l) aquaria contained 0.001-0.004 mg/l after 5 weeks; water in tanks with sand contained 0.046-0.050 and 0.029-0.037 mg As/l, respectively. Lake sediments contained 0.40-0.68 mg As/kg dry wt in large tanks and 0.28-0.51 in small tanks; sand contained only 0.13-0.18 mg As/kg in large tanks and 0.08-0.12 in smaller microcosms. Arsenic concentrations, in mg/kg dry wt, in algae communities with sediment were 10.5 to 19.1 in 70 l tanks and 6.0 to 12.9 in smaller tanks and with sand were 33.8 to 65.7 in large and 9.3 to 14.3 in small tanks; levels in snails were 1.8 to 3.3, 1.2 to 1.5, 0.44 to 0.58, and 0.37 to 0.79, respectively, and in zooplankton were 6.8 in 70 l tanks with sediment and 8.3 to 10.4 in 70 l tanks with sand. Maximum bioaccumulation ratios over water were in sediment microcosms; ranging from 970 to 9190 for algae, 164 to 1030 for snails, and 630 for zooplankton.

2645. Greichus, Y.A., A. Greichus, B.D. Amman, D.J. Call, D.C.D. Hamman, and R.M. Pott. 1977. Insecticides, polychlorinated biphenyls and metals in African lake ecosystems. I. Hartbeespoort Dam, Transvaal and Voelvlei Dam, Cape Providence, Republic of South Africa. Arch. Environ. Contamin. Toxicol. 6:371-383.

Average metal concentrations in Hartbeespoort Dam and Voelvlei Dam in water, respectively, were 0.001 and 0.003 mg As/l, <0.001 and 0.002 for Cd, 0.003 and 0.013 for Cu, 0.045 and 0.038 for Mn, 0.004 and 0.012 for Pb, 0.036 and 0.025 for Zn, and <0.001 for Hg; levels in sediments were 75 and 16 mg As/kg dry wt, 0.87 and 0.19 for Cd, 41 and 15 for Cu, 680 and 340 for Mn, 63.0 and 9.0 for Pb, 260 and 49 for Zn, and 0.6 and 0.06 for Hg. In fish composite samples these values were 2.3 and 2.3 mg As/kg dry wt, 0.05 and 0.06 for Cd, 2.9 and 3.8 for Cu, 12.0 and 9.2 for Mn, 1.0 and <0.1 for Pb, 120 and 55 for Zn, and 0.52 and 0.39 for Hg. In Hartbeespoort, algae contained 1.5 mg As/kg dry wt, 0.06 Cd, 2.7 Cu, 96 Mn, <0.1 Pb, 39 Zn, and 1.6 Hg; water hyacinth contained 4.1, 0.23, 12, 840, 2.6, 42, and 0.71, respectively. Worms from Voelvlei contained 5.2 mg As/kg dry wt, <0.01 for Cd, 21 for Cu, 15 for Mn, 5.1 for Pb, and 41 for Zn; insects contained 5.2, 0.09, 22, 28, 5.6, and 78, respectively. Metal levels in carcasses of fish-eating birds were, for cormorants from Hartbeespoort and darters from Voelvlei, respectively, 1.7 and 1.3 mg As/kg dry wt, 0.59 and 0.05 for Cd, 4.8 and 6.3 for Cu, 8.8 and 5.0 for Mn, 2.4 and 0.28 for Pb, 130 and 62 for Zn, and 1.6 and 1.1 for Hg. In general, metal concentrations were higher in feathers and lower in brain tissue than in carcasses. Darter eggs without shells contained 2.3 mg As/kg dry wt, <0.01 for Cd, 5.8 for Cu, 1.3 for Mn, < 0.1 for Pb, 41 for Zn, and 0.84 for Hg. Hartbeespoort Dam had higher levels than Voelvlei for all metals in sediments and birds except Cu in carcasses. Mercury levels in bird carcasses ranged from 2 to 5X greater than fish, and lead ranged from 2 to 10X higher.

2646. Greig, R.A., D.R. Wenzloff, A. Adams, B. Nelson, and C. Shelpuk. 1977. Trace metals in organisms from ocean disposal sites of the middle eastern United States. Arch. Environ. Contamin. Toxicol. 6:395-409.

Concentrations of Ag, As, Cd, Cr, Cu, Hg, Mn, Pb, and Zn were determined for marine fish and shellfish collected near 3 ocean dumping sites, 3 inshore areas, and a control site. Silver in flesh of rock crabs *Cancer irroratus* averaged 0.79 mg/kg wet wt in the New York Bight disposal site compared with 0.24-0.38 mg Ag/kg for 4 other areas. Cadmium, manganese, and zinc concentrations were highest in crab flesh from Long Island Sound, not a known disposal site, compared to 3 other areas; mean levels were 1.0 mg Cd/kg wet wt *vs* 0.1, 29 mg Mn/kg *vs* 0.8-1.0, and 64 mg Zn/kg *vs* 32-36. Mn content in crab gills was 22 mg/kg from the Sound compared to 6.0 mg/kg in crabs from Chincoteague Inlet, Virginia. Crab flesh from all sites contained about 1.9 mg As/kg wet wt, <0.3-0.6 mg Cr/kg, and 0.15-0.19 mg Hg/kg. Digestive glands of channel whelks *Busycon canaliculatum* from Long Island Sound disposal site contained maximum amounts of silver, cadmium, and zinc at 20 mg Ag/kg wet wt, 24 mg Cd/kg, and 2650 mg Zn/kg, and a high level of copper at 1100 mg/kg wet wt. Metal concentrations in surf clams *Spisula solidissima* and windowpane flounder *Scophthalmus aquosus*, and arsenic, chromium, and mercury in all organisms did not vary significantly among geographic areas. Clam and whelk muscle contained <0.2 mg Ag/kg wet wt, 1.3-9.0 mg As/kg, <0.1-0.21 mg Cd/kg, <0.8 mg Cr/kg, 0.9-21.0 mg Cu/kg, <0.05-0.14 mg Hg/kg, 0.5-3.5 mg Mn/kg, <0.5-0.9 mg Pb/kg, and 18.4-29.5 mg Zn/kg. Flounder flesh contained <0.1 mg Ag/kg wet wt, 1.4-2.8 mg As/kg, < 0.1 mg Cd/kg, <0.2-0.6 mg Cr/kg, 0.7-1.4 mg Cu/kg, 0.12-0.27 mg Hg/kg, 0.18-0.40 mg Mn/kg, <0.5-1.0 mg Pb/kg, and 4.6-6.3 mg Zn/kg. Ranges in metal content of sediments from the 3 dumping sites, in mg/kg dry wt, were <1.0 for Ag, <1.0 for Cd, <2.0 to 58.0 for Cr, <4.0 to 86.0 for Cu, <0.1 to 0.2 for Hg, 13.0 to 280.0 for Mn, 3.6 to 97.0 for Pb, and 5.6 to 154.0 for Zn.

2647. Horowitz, A. and B.J. Presley. 1977. Trace metal concentrations and partitioning in zooplankton, neuston, and benthos from the south Texas Outer Continental Shelf. Arch. Environ. Contamin.

Toxicol. 5:241-255.

Marine biota collected along the Texas Outer Continental Shelf were analyzed for Cd, Cr, Cu, Fe, Mn, Ni, Pb, and Zn. Average metal concentrations, in mg/kg dry wt in zooplankton were 13.4 for Cu, 103 for Zn, 3.0 for Cd, 8.0 for Pb, 5.6 for Cr, 4.6 for Ni, 725 for Fe, and 29.7 for Mn; sargassum contained average levels of 4.1, 36.0, 1.8, 4.7, 1.6, 5.2, 218, and 31.4, respectively; plankton contained 8.1, 90.8, 1.9, 12.1, 5.0, 4.4, 624, and 21.7, respectively; squid contained 65.7, 144, 1.0, 2.0, 4.7, 2.5, 19.3, and 1.8, respectively in flesh including skin; brown and rock shrimp contained 24.2-31.1, 47.7-56.3, 0.16-0.25, 1.1-1.6, 2.1-2.8, 1.4-1.6, 14.2-40.2, and 1.5-8.0, respectively. Muscle from flatfish, long-spined porgy, rough scad, sea robin, sand sea trout, black-ear bass, Atlantic croaker, and wenchman contained average metal levels of 1.1-3.4 for Cu, 15.5-59.3 for Zn, 0.08-0.26 for Cd, 0.8-6.5 for Pb, 2.0-8.1 for Cr, 0.6-4.9 for Ni, 7.7-177.0 for Fe, and 0.4-18.4 for Mn, all on a dry wt basis. Lead concentrations in organisms increased from north to south and cadmium increased from nearshore to offshore, reflecting sediment patterns. Exoskeletons of shrimp and skin of squid and fishes generally had higher metal levels than flesh, possibly the result of adsorption from seawater or internal detoxification by the organism. Enriched Cd, Cu, Fe, Pb, and Zn levels found in squid "pens" may be attributed to internal detoxification or storage of necessary metabolites, but not to adsorption since the pen is imbedded in tissue and not exposed to seawater.

2648. Johnson, G.D., A.W. McIntosh, and G.J. Atchison. 1978. The use of periphyton as a monitor of trace metals in two contaminated Indiana lakes. Bull. Environ. Contamin. Toxicol. 19:733-740.

Concentrations of cadmium and zinc were determined in two Indiana lakes which received effluents from nearby electroplating facilities. In Palestine Lake, metal levels in water at 6 sites ranged from 0.0018 to 0.0098 mg Cd/l, and in algae from 80 to 430 mg Cd/kg dry wt, with two low concentrations of 5.6 and 8.8 mg/kg. Zinc levels in Palestine Lake ranged from 0.03 to 0.27 mg/l in water and from 330 to 13,000 mg/kg dry wt in algae. Water samples from Little Center Lake extended from 0.0007 to 0.0027 mg Cd/l and algal samples from 27 to 54 mg Cd/kg dry wt; concentrations of Zn were 0.032 to 0.087 mg/l and 900 to 9700 mg/kg dry wt, respectively. Algal metal concentrations did not always correlate to water concentrations at each site, but maximum levels of both Cd and Zn in algae and water were found at sites nearest to industrial outfalls in both lakes.

2649. Liu, M.S. and J.A. Hellebust. 1976. Effects of salinity changes on growth and metabolism of the marine centric diatom *Cyclotella cryptica*. Canadian Jour. Botany *54:930-937.*

Growth rates of euryhaline diatoms were about 2 cell divisions/day after 0-2 days acclimation in salinities of 10 to 50% SW (100% equals 34 o/oo S). Growth was reduced in salinities of 80% to 150% SW, but division was still >1 division per day, with a longer lag phase prior to logarithmic growth. Transfer of diatoms from 33% SW to higher salinities of 50 to 150% SW resulted in temporary plasmolysis and decreased photosynthetic and protein synthesis. Rapid accumulation of free amino acids, including proline, either from photoassimilated carbon or from heterotrophic assimilation of glucose in the dark also occurred. On transfer to low salinities, diatoms rapidly decreased amino acid concentrations. Contents of chlorophylls *a* and *c* varied little, from 5 and 3 million ug/cell, respectively, after 6 days in middle salinities of 33 to 100% SW, but levels dropped to 2-3.5 million and 2-2.5 million, respectively, at both high and low salinity extremes.

2650. Liu, M.S. and J.A. Hellebust. 1976. Effects of salinity and osmolarity of the medium on amino acid metabolism in *Cyclotella cryptica*. Canadian Jour. Botany *54:938-948.*

Diatoms subjected to a sudden increase in salinity, from 33% to 80% SW (100% SW = 34 o/oo S), exhibited a reduction in total uptake of amino acids and subsequent assimilation into proteins within 2 hrs. Under water-stress conditions, proline was synthesized from glutamate, arginine, and ornithine. Increases in medium osmolarity, whether by KCl, mannitol, or sucrose, but not glycerol, increased synthesis of proline and levels of intracellular K and total amino acids. Proline levels were reduced when diatoms were retransferred to low osmolarity media. Loss of C-14 from proline was accompanied by incorporation into proteins and by conversion of proline into other cell components. Addition of salts and organic matter to low salinity media, or KCl or glycerol alone, caused plasmolysis followed by rapid deplasmolysis. Proline levels were relatively low in high-salinity adapted diatoms and proline turned over rapidly. Authors suggest that proline accumulation is a response to abrupt changes of intracellular ionic strength during adaptation to increased salinity.

2651. Merlini, M. 1978. Hepatic storage alteration of vitamin B_{12} by cadmium in a freshwater fish. Bull. Environ. Contamin. Toxicol. 19:767-771.

Sunfish, Lepomis gibbosus, were pretreated for 2 weeks with 0.04 mg $CdSO_4$/l in lake water. Subsequently, these and controls were fed a single ration containing vitamin B_{12} labelled with Co-58. Five days later, amounts of labelled vitamin B_{12} were 3900 cpm/g in controls and 3700 cpm/g in experimentals. Relative concentration (R) of labelled vitamin in tissue divided by amount in whole fish was significantly higher in liver of control fish at 74 than treated specimens at 45; R was significantly lower in controls for digestive tract at 3.1 compared to 5.7, gall bladder at 7.2 to 15.1, and head 0.3 to 0.5. No difference in R was found between groups for kidney and body residue. Controls were able to stock vitamin B_{12} in liver. Cadmium appeared to accelerate vitamin elimination, as shown by higher levels in digestive tract of Cd-exposed fish, by stimulating biliary excretion into the digestive tract with excretion via gills.

2652. Morishita, H. and H. Takada. 1976. Sparing effect of lithium ion on the specific requirement for sodium ion for growth of Vibrio parahaemolyticus. Canadian Jour. Microbiol. 22:1263-1268.

Maximal growth of the bacteria V. parahaemolyticus was obtained at 29,250 mg NaCl/l in a synthetic medium. When the medium was kept isotonic with 29,250 mg NaCl/l by sucrose, good growth was obtained with 5850 mg NaCl/l. By reducing osmotic pressure and decreasing NaCl to 5850 mg/l, the same growth was obtained with 11,700 mg NaCl/l and 3400 mg LiCl/l; this was not the case for sucrose addition. Authors concluded that ionic strength and osmotic pressure, besides Na, were important environmental factors affecting growth. Minimal essential sodium requirement for Vibrio growth was 69 mg Na^+/l, since this was not replaced by any other cation. Osmotic support was required when NaCl was decreased to 2925 mg/l. Of LiCl, KCl, RbCl, and NH_4Cl added to 175.5 mg NaCl/l, Li^+ was the most accelerative for growth in synthetic media.

2653. Oguri, M. and Y. Ooshima. 1977. Early changes in the plasma osmolarity and ionic concentrations of rainbow trout and goldfish following direct transfer from fresh-water to sea water. Bull. Japan. Soc. Sci. Fish 43:1253-1257.

When transferred from freshwater to full seawater with an osmolarity of about 1000 mOsm/l, plasma osmolarity of euryhaline rainbow trout, *Salmo gairderi*, increased from 310 to 345 mOsm/l within 15 min, *then declined* gradually over the next 45 min to 330 mOsm/l. During 60 min in seawater, plasma Na increased slightly from 3565 to 3910 mg/l and plasma Cl increased from 42,600 to 47,900 mg/l. No trout mortality was observed. Goldfish, *Carassius auratus*, which are stenohaline freshwater fishes, *all died within an* average of 33 min when transferred directly to full seawater. During this period, plasma osmolarity rose sharply from 275 to 350 mOsm/l, plasma Na level rose from 3220 to 4140 mg/l, and plasma Cl from 37,300 to 55,000 mg/l.

2654. Reimer, A.A. and R.D. Reimer. 1975. Total mercury in some fish and shellfish along the Mexican coast. Bull. Environ. Contamin. Toxicol. 14:105-111.

Fish and shellfish obtained from local markets, packing houses, or fishermen along the Gulf and Pacific coasts of Mexico were analyzed for mercury. Highest mean levels were found in the teleosts *Mugil curema*, *Sphyraena guachancho*, and *Polynemus virginica* from Veracruz and *Centropomus* sp. from Coatzacoalcos markets, ranging from 0.04 to 0.27 mg Hg/kg wet wt. Gray mullet, *Mugil cephalus*, from Tampico, Guaymas, Tololobampo, and Mazatlan fish markets contained mean mercury levels of 0.03 to 0.07 mg/kg wet wt in muscle and 0.01 to 0.09 in liver. Mojarra, *Anisotremus interruptus* and white mojarra, *Diapterus* sp., contained 0.12 and 0.06 mg Hg/kg wet wt, respectively, in muscle and 0.26 and 0.07 in liver. The shrimps *Penaeus aztecus*, *P. setiferus*, *P. californiensis*, and *P. stylirostris* contained 0.05 to 0.12 mg Hg/kg wet wt in muscle. Mean mercury concentrations in bivalve molluscs *Crassostrea virginica*, *Codakia orbicularis*, and *Anadara tuberculosa* ranged from 0.02 to 0.09 mg/kg wet wt. Maximum levels found in individual specimens were 0.61 mg Hg/kg in whole fish, 0.64 in fish muscle, and 0.47 in fish liver, 0.67 in shrimp muscle, and 0.22 in bivalves.

2655. Simola, L.K. 1977. The effect of lead, cadmium, arsenate, and fluoride ions on growth and fine structure of Sphagnum nemoreum in aseptic culture. Canadian Jour. Botany 55:426-435.

The highest concentration tested having little effect on growth of bog moss, Sphagnum nemoreum, during a period of 100 days was 20,700 mg/l lead, 1120 mg/l cadmium, and 75 mg/l arsenate. Inocules died rapidly in 75,000 mg As/l as Na_2HAsO_4 or 11,200 mg Cd/l as $CdSO_4$; 207,000 mg Pb/l as $Pb(NO_3)_2$ was growth-retarding. Chloroplasts accumulated starch and hyaline cell differentiation was inhibited in 7500 mg As/l. Cytoplasm accumulated lipids in 20,700 mg Pb/l.

2656. Sims, R.R., Jr. and B.J. Presley. 1976. Heavy metal concentrations in organisms from an actively dredged Texas bay. Bull. Environ. Contamin. Toxicol. 16:520-527.

In general, crustaceans, molluscs, and fish from San Antonia Bay, Texas, a site of active dredging, had lower concentrations of heavy metals than organisms from areas where dredging and pollution are thought to be minimal. Soft portions of oysters, Crassostrea virginica, contained an average of 1.3 mg As/kg dry wt, 3.2 Cd, 161.0 Cu, <0.8 Pb, 0.05 Hg, and 322.0 Zn. Clams, Rangia cuneata, contained 0.5 mg Cd/kg dry wt, 25.0 Cu, 1.1 Pb, and 51.0 Zn. Average concentrations in brown shrimp were 0.6 mg As/kg wet wt, <0.4 for Cd, 34.0 for Cu, <0.2 for Pb, <0.02 for Hg, and 14.0 for Zn, and in blue crabs were 0.6 for As, 0.1 for Cd, 54.0 for Cu, <0.2 for Pb, and 14.0 for Zn. Metal levels, in mg/kg dry wt, in whole body and flesh of the fishes, Atlantic croaker, silverside, spot, white sea trout, spotted sea trout, bay anchovy, menhaden, gizzard shad, and southern flounder, ranged from <0.1 to 1.8 Cd, 1.3 to 4.3 Cu, <0.2 to 2.3 Pb, and 6.3 to 117.0 Zn. Maximum metal concentrations, in mg/kg dry wt, reported for organisms from unpolluted and undredged areas along the U.S. coast were: in bivalves, <1.6 As, 40.0 Cd, 126 Cu, 7.7 Pb, 0.45 Hg, and 1533 Zn; in shrimp and crabs, 11.0 As, 0.4 Cd, 34.0 Cu, 0.2 Pb, 0.24 Hg, and 75.0 Zn; and in fishes, 6.1 Cd, 10.0 Cu, 8.6 Pb, and 397 Zn.

2657. Sorensen, E.M.B. 1976. Thermal effects on the accumulation of arsenic in green sunfish, Lepomis cyanellus. Arch. Environ. Contamin. Toxicol. 4:8-17.

Arsenic uptake increased in liver, gut, and muscle of sunfish with increasing temperature (10 to 30 C), concentration of As (0.0 to 60 mg/l as sodium arsenate), and time of exposure (up to 5 wks). Maximum accumulation in liver was 1460 mg As/kg wet wt in 60 mg As/l at 30 C for 2 wks, and at 1090 mg As/kg in 30 mg/l at 20 C for 4 wks. Maximum gut uptake was 240 mg As/kg wet wt in 60 mg As/l at 20 or 30 C for 2 wks, and at 250 mg/kg in 30 mg/l at 20 C for 4 wks. Maximum muscle uptake was 80 mg As/kg wet wt in 30 mg As/l at 30 C for 2 wks, and at 60 mg As/kg in 60 mg/l at 20 C for 4 wks. Mean temperature quotient (Q_{10}) values for As uptake in liver was 4.5. Other Q_{10} values for the genus Lepomis range from 1.6 to 3.0. Higher Q_{10} values suggest that elevated temperatures and high metal concentrations act synergistically in metal uptake. Biological half-life of As in liver and gut of fish exposed to 30 and 60 mg As/kg at 10 C was about 1 wk. LT-50 times in 60 mg As/l were 678 hrs at 10 C, 210 hrs at 20 C, and 124 hrs at 30 C; LT-50 times in 30 mg As/l were 527 hrs at 20 C and 209 hrs at 30 C.

2658. Talbot, V. and R.J. Magee. 1978. Naturally-occurring heavy metal binding proteins in invertebrates. Arch. Environ. Contamin. Toxicol. 7:73-81.

Low molecular weight cadmium, copper, and zinc binding proteins have been isolated from mussels, Mytilus edulis, collected from the cadmium polluted areas of Corio Bay, Australia. Of 3 protein fractions, fraction II contained the major proportion of Cd at 0.46 mg/kg, Cu at 0.20 mg/kg, and Zn at 0.20 mg/kg. Fraction III contained 0.44 mg Cd/kg, 0.20 mg Cu/kg, and 0.20 mg Zn/kg, and fraction I contained 0.14 mg Cd/kg, 0.10 mg Cu/kg, and 0.03 mg Zn/kg. Authors suggest that the synthesis of this protein, which probably belongs to the metallothionein family of metal binding proteins, was induced in cyctoplasmic solutions in cells as a regulatory mechanism to avoid intoxication by excess uptake of metals.

2659. Ueda, T., and M. Takeda. 1977. On mercury and selenium contained in tuna fish tissues - IV. methyl mercury level in muscles and liver of yellowfin tuna. Bull. Japan. Soc. Sci. Fish. 43:1115-1121.

Concentrations of methylmercury in 39 specimens of yellowfin tuna, Thunnus albacares, averaging 35.0 kg in weight, from the Middle Pacific, West Pacific, and East Indian Oceans, ranged from 0.04 to 0.46 mg CH_3Hg/kg wet wt in dark muscle with a mean of 0.21, from 0.02 to 0.41 mg CH_3Hg/kg in dorsal muscle with a mean of 0.19, and from 0.01 to 0.40 mg CH_3Hg/kg in liver with a mean of 0.11. Concentrations of methylmercury in other tissues were 0.16-0.27 mg/kg in abdominal muscle, 0.06-0.10 in spleen, and 0.06-0.07 in kidney. Methylmercury levels were directly correlated to total mercury in both dorsal and dark muscles and liver. Total mercury content was significantly greater than methylmercury in dorsal muscle, averaging about 0.04 mg/kg higher. No difference was noted between the two mercury forms in dark muscle or liver. Order of mercury levels in tissues was estimated as: total Hg of dorsal muscle $\approx$ total Hg of dark muscle $\approx$ methyl Hg of dark muscle $>$ methyl Hg of dorsal muscle $>$ methyl Hg of liver $\approx$ total Hg of liver.

2660. Anderson, D.M. and F.M.M. Morel. 1978. Copper sensitivity of *Gonyaulax tamarensis*. Limnol. Oceanogr. 23:283-295.

Short term responses of the dinoflagellate *G. tamarensis* to copper included rapid loss of motility and reduced photosynthetic carbon fixation. Toxicity was a unique function of cupric ion activity, as demonstrated by chelators tris hydroxymethylaminomethane (Tris) and ethylenedinitrilotetraacetic acid (EDTA). Copper additions to EDTA medium equilibrated with the chelator relatively slowly, resulting in misleading short term data. This kinetic effect was not seen with Tris or when copper was added in chelated form with EDTA. Variations in manganese or zinc concentrations over two orders of magnitude did not alter results. Cells of *G. tamarensis* were 100% nonmotile at a calculated cupric ion activity of $10^{-9.7}$ M, with 50% of cells nonmotile at $10^{-10.4}$ M. Nonmotile cells did not divide or grow larger. Growth was totally inhibited at cupric ion activities that only partially inhibited growth of four other species. Since toxicity occurred at the calculated copper activity of natural waters, assuming only inorganic copper complexation, authors concluded that organic chelation may be necessary before *G. tamarensis* can successfully compete with other algal species in coastal waters.

2661. Anderson, R.V. and J.E. Brower. 1978. Patterns of trace metal accumulation in crayfish populations. Bull. Environ. Contamin. Toxicol. 20:120-127.

Metal concentrations in whole crayfish, Orconectes virilis, from 3 sites in Illinois were : 2.22 mg Cd/kg dry wt from an Elgrin river, 1.04 from an Elgrin pool, and 1.09 from an Algonquin river; 64.3 mg Cu/kg dry wt, 61.2, and 71.3, respectively; 27.4 mg Pb/kg dry wt, 8.4, and 11.3, respectively; and 78.3, 87.1, and 101.3, mg Zn/kg dry wt. Previous data showed that metal levels were generally higher in Elgrin water, sediment, and biota than similar data from the Algonquin. No significant differences in metal concentrations were evident between sexes of crayfish and no consistent trends existed among size classes of these freshwater crustaceans. Maximum metal levels were found in gills for Cd at 1.5 mg/kg dry wt and for Cu at 120.7, in gills and viscera for Zn at 82.0 and 82.4 mg/kg, respectively, and in exoskeleton for Pb at 23.4 mg/kg. Muscle had the lowest concentrations of all metals tested except Zn.

2662. Barbaro, A., A. Francescon, B. Polo, and M. Bilio. 1978. Balanus amphitrite (Cirripedia:Thoracica) - a potential indicator of fluoride, copper, lead, chromium, and mercury in North Adriatic lagoons. Marine Biology 46:247-257.

The capacity of barnacles to accumulate pollutants above ambient levels was examined in two North Adriatic lagoons. Levels in soft tissues ranged from 41 to 109 mg/kg dry wt for copper, 7 to 12 for lead, 2 to 4 for chromium, and from 1.0 to 1.4 for mercury. Concentration factors were about 1000 for Cu, and possibly higher than 1000 for Pb, Cr, and Hg. B. amphitrite that had set on experimental panels had levels similar to those found in specimens collected from long-term natural populations as early as 42 days after immersion of panels. Compared with literature data, accumulation levels found in B. amphitrite for copper and lead were considerable, but exceeded by others published for B. balanoides; chromium and mercury were 10X lower than values reported for other suspension-feeders or indicator organisms. It was concluded that B. amphitrite possesses most of the properties considered essential for a biological indicator. Eventual determination of response time of barnacles to changes in environmental level could profitably be carried out utilizing experimental panels.

2663. Bohm, L. 1978. Application of the ^{45}Ca tracer method for determination of calcification rates in calcareous algae: effect of calcium exchange and differential saturation of algal calcium pools. Marine Biology

47:9-14.

Calcium exchange and differential saturation of algal calcium pools complicate application of the Ca-45 tracer method for determination of net deposition rates of Ca in calcareous algae. Calcium incorporation occurs in two stages: a fast stage, saturating exchangeable Ca pools, and a slow stage, giving rise to net deposition. Reliability of the method depends on determination of the second rate constant. Calcium exchange and recycling of tracer lower the second rate constant, hence the method gives rise to minimum values. Application of the method was demonstrated for the following algae: Halimeda incrassata, H. opuntia, Penicillus pyriformis, Udotea flabellum, Cymopolia barbata, Padina sanctae crucis and Amphiroa fragilissima. Calculated rate constants ranged from 67 to 220 cpm/mg/hr. Results show close agreement of data with independent chemical estimates.

2664. Borgmann, U., O. Kramar, and C. Loveridge. 1978. Rates of mortality, growth, and biomass production of Lymnaea palustris during chronic exposure to lead. Jour. Fish. Res. Bd. Canada 35:1109-1115.

Chronic exposure of freshwater snails, L. palustris, to lead nitrate as low as 19 ug Pb/l significantly increased mortality, but did not affect growth during immersion from newly hatched eggs until reproductive maturity. Lead-induced mortality was proportional to Pb concentration raised to the power of 2.5. Mortality as a rate function was superior to LC-50 or LT-50 values. A 50% drop in biomass production rate was observed at 36 ug Pb/l; and zero production at 48 ug/l. Lead uptake in whole snails was proportional to lead concentration, with a concentration factor of 8500 per dry weight.

2665. Brown, D.A., and T.R. Parsons. 1978. Relationship between cytoplasmic distribution of mercury and toxic effects to zooplankton and chum salmon (Oncorhynchus keta) exposed to mercury in a controlled ecosystem. Jour. Fish. Res. Bd. Canada 35:880-884.

After exposure for 72 days to mercuric chloride, total cytoplasmic Hg in salmon liver increased from 0.12 mg Hg/kg wet wt in controls to 0.17 mg/kg in 1.0 ug Hg/l and 0.95 mg/kg in 5.0 ug Hg/l. Copper decreased from 114 to 89 mg/kg wet wt and zinc decreased from 10.5 to 7.2 mg/kg in cytoplasm of liver as Hg increased in fish exposed to 5.0 ug Hg/kg. Total cytoplasmic Hg in tissue of zooplankton increased from 0.08 mg Hg/kg wet wt in controls to 3.9 mg/kg after 72 day exposure to 5.0 ug Hg/l; coincidental loss of Cu and Zn also occurred. Pathological effects coincided with saturation of metallothionein and "spillover" of Hg into the high molecular weight protein (enzyme-containing) pool. Tertiary and quaternary structural changes in metalloenzymes resulted from replacement of Cu and Zn by Hg. Decreases in tissue Cu and Zn with increasing Hg concentration are discussed as an intracellular displacement of metals and as duodenal and cellular exclusion processes.

2666. Cardwell, R.D., C.E. Woelke, M.I. Carr, and E. Sanborn. 1978. Variation in toxicity tests of bivalve mollusc larvae as a function of termination technique. Bull. Environ. Contamin. Toxicol. 20:128-134.

Toxicities of cadmium, methoxychlor, and dodecyl sodium sulfate to larvae of oysters *Crassostrea gigas* and clams *Tresus capax* were compared between direct sampling of larvae and filtering larvae before sampling. For oysters, EC-50 for abnormal shell development was 1.3 mg Cd/l with filtering and 0.9 mg/l without filtering; LC-50 values were 0.9 mg Cd/l filtered and 2.5 unfiltered. For clams, EC-50 values were 0.05 mg Cd/l for both filtered and unfiltered samples; LC-50 values were 0.1 mg Cd/l filtered and 0.7 mg/l unfiltered. Authors concluded that filtering resulted in loss of smaller larvae from test populations and that a greater proportion of those lost were abnormal.

2667. Cawthorne, D.F. 1978. Tolerance of some cirripede nauplii to fluctuating salinities. Marine Biology 46:321-325.

Effects of fluctuating salinity on mortality of newly released nauplii of three species of barnacles, *Elminius modestus*, *Balanus balanoides*, and *B. hameri*, were measured. Larvae were exposed to three different types of salinity regimes. In all cases, a regime which fluctuated between 100% seawater (33.5 o/oo S) and a reduced concentration of about 15% SW in a 12 hr cycle was found to be least damaging. Abruptness of salinity shock and degree of exposure to reduced salinity each influenced mortality, but it was concluded that abruptness of change was the more important. Mortality of barnacles dropped below 10% when minimum seawater dilution encountered for 24 hrs was 15 to 25% for *E. modesta*, 25 to 30% for *B. balanoides*, and 25 to 40% for *B. hameri*.

2668. Chisholm, S.W., F. Azam, and R.W. Eppley. 1978. Silicic acid incorporation in marine diatoms on light:dark cycles: use as an assay for phased cell division. Limnol. Oceanogr. 23:518-529.

Silicon incorporation in diatom populations grown on light:dark cycles was monitored using [Ge-68]$Ge(OH)_4$ as a tracer for $Si(OH)_4$. Frustule formation closely followed the time-course of cell division in all 6 species examined (*Thalassiosira pseudonana*, *T. fluviatilis*, *Chaetoceros gracilis*, *Ditylum brightwelli*, *Lithodesmium undulatum*, *Skeletonema cestatum*). Timing of these processes relative to light:dark cycle was different for each species. Maximum silicic acid uptake over 24 hrs ranged from 0.96 to 2.11 mg $Si(OH)_4$/diatom sample; incorporation reached 2.11 mg $Si(OH)_4$/sample for one species. Seawater samples from the Gulf of California and Southern California Bight also showed periodicity in $Si(OH)_4$ incorporation when incubated under ambient light and surface temperature. Authors concluded that degree of periodicity is inversely correlated with diatom species diversity in samples, consistent with the hypothesis that pulses in $Si(OH)_4$ incorporation reflect phased cell division in individual species of diatoms.

2669. Chou, C.L., J.F. Uthe, and E.G. Zook. 1978. Polarographic studies on the nature of cadmium in scallop, oyster, and lobster. Jour. Fish. Res. Bd. Canada 35:409-413.

Free and bound forms of cadmium were determined in raw shellfish by differential pulse polarography and atomic absorption spectrophotometry. Total cadmium in muscle of various species of scallops averaged 5.3 mg/kg wet wt; in oyster species tissue Cd was 0.8 mg/kg, and in lobsters *Homarus americanus* 0.03 mg/kg. Both scallop and lobster muscle contained no free cadmium. Oyster had about 50% of its total cadmium present in free form, a phenomena as yet unexplained. Detection limit for free Cd was 0.05 mg/kg raw tissue.

2670. Fowler, S.W., M. Heyraud, and J. La Rosa. 1978. Factors affecting methyl and inorganic mercury dynamics in mussels and shrimp. Marine Biology 46:267-276.

Accumulation and loss of inorganic and methylmercury in mussels, Mytilus galloprovincialis, and benthic shrimp, Lysmata seticaudata, were studied with radiotracers. Methylmercury was accumulated by both species from both water and food (labelled phytoplankton) to a greater degree than inorganic mercury. In the temperature range 8 to 18 C, accumulation was slightly greater at higher temperatures. After 5 days in 18 C, mussels had concentration factors of 500 for CH_3HgCl and 375 for $HgCl_2$. Small mussels averaging 1.7 gm wet wt concentrated more mercury than larger mussels weighing 5.0 gm; the reason remains unclear. Viscera contained the largest fraction of total body Hg, at 46% in shrimp and 16% in mussels. Methylmercury was eliminated by both animals more slowly than inorganic mercury; loss was slightly faster at higher temperatures of 23 C. Mussels maintained in their natural environment had enhanced Hg elimination attributed to availability of food and subsequent growth. Authors concluded that observed differences underscore the need for caution in predicting in situ flux of metals such as mercury in certain species based solely on data derived from laboratory experiments.

2671. George, S.G., B.J.S. Pirie, A.R. Cheyne, T.L. Coombs, and P.T. Grant. 1978. Detoxication of metals by marine bivalves: an ultrastructural study of the compartmentation of copper and zinc in the oyster Ostrea edulis. Marine Biology 45:147-156.

Mechanisms of detoxication of copper and zinc by oysters was investigated using Cu-impacted and non-perturbed populations. Oysters from polluted areas contained 21 mg Cu/l and 160 mg Zn/l in whole hemolymph and 220 mg Cu/kg wet wt and 1260 mg Zn/kg in soft tissue. Gills and mantle contained highest metal concentrations of 2400 and 2200 mg Cu/kg wet wt, respectively. and 15,000 and 13,000 mg Zn/kg, respectively. Specimens from unpolluted areas contained 2 mg Cu/l and 60 mg Zn/l in hemolymph and 23 mg Cu/kg wet wt and 590 mg Zn/kg in whole tissue. Gills contained 250 mg Cu/kg and 10,000 mg Zn/kg and mantle 2200 mg Cu/kg and 6200 mg Zn/kg. Copper and zinc were compartmentalized in separate, specific, granular amoebocytes and immobilized in membrane-limited vesicles as different chemical compounds. Copper was associated with sulphur and zinc with phosphorus. Chemical analyses of serum and tissues of normal and contaminated oysters indicated that Cu and Zn are accumulated independently; that Cu and Zn in serum, while higher than in surrounding seawater, are maintained at a 10X lower level than tissues; and that toxicity is reduced by active uptake from serum into granular amoebocytes, where it is further reduced by compartmentation in membrane-limited vesicles. Individual cell types may contain as much as 13,000 mg Cu/kg and 25,000 mg Zn/kg.

2672. Glover, H.E. 1978. Iron in Maine coastal waters; seasonal variation and its apparent correlation with a dinoflagellate bloom. Limnol. Oceanogr. 23:534-537.

Soluble iron concentrations in the top 20 m of water off Boothbay Harbor, Maine, were 4.0-5.0 ug Fe/l in October and November 1975 during the fall dinoflagellate bloom. These concentrations were 3X greater than levels encountered in August and September. Particulate iron levels increased to 3.5 ug Fe/l prior to the bloom (mainly Gymnodinium sp.). Nutrient enrichment and other experiments indicated that low iron concentrations limited phytoplankton populations. In August, 1976, increased iron concentrations from land runoff, near Monhegan Island, preceded a dinoflagellate bloom.

2673. Gnassi-Barelli, M., M. Romeo, F. Laumond, and D. Pesando. 1978. Experimental studies on the relationship between natural copper complexes and their toxicity to phytoplankton. Marine Biology 47:15-19.

Toxicity of copper to phytoplankton depends on the metal's physicochemical form. Organic substances liberated into the culture medium by Cricosphaera elongata are able to detoxify and complex copper. Molecular weight ranges of these organic substances were determined by ultrafiltration. Over 50% of 0.025 mg Cu/l added to medium was found in the 500-1000 MW and 1000-10,000 MW fractions. Growth of Cricosphaera was inhibited by a minimum of 0.025 mg Cu/l in seawater and 0.05 mg Cu/l in culture medium.

2674. Goldberg, E.D., V.T. Bowen, J.W. Farrington, G. Harvey, J.H. Martin, P.L. Parker, R.W. Risebrough, W. Robertson, E. Schneider and E. Gamble. 1978. The mussel watch. Environ. Conserv. 5:101-125.

Environmental research has suggested that some bivalves, namely Mytilus edulis, M. californianus, Crassostrea virginica, and Ostrea equestris may be valuable as sentinel organisms for indicating levels of pollutants in coastal marine waters. These organisms concentrate numerous pollutants to a marked degree over seawater levels. Several species thus bioaccumulate some, or even most, members of the four identified categories of marine pollutants: heavymetals, transuranic elements, petroleum hydrocarbons, and halogenated hydrocarbons. A given species, however, may have unique enrichment factors for any or all of these groups of substances. Baseline levels of pollutants in molluscan tissues from U.S. coastal waters have been determined for the year 1976. Zones of high pollutant concentrations have been identified. No significant seasonal variations of Ag, Cd, Cu, Ni, Pb and Zn concentrations were observed in the monthly samples taken at Narragansett Bay, RI, or at Bodega Head or Point La Jolla, California. No zones of high general levels of metal pollution were discerned, although locally high levels of individual metals were frequently observed. Oysters were much more effective bioaccumulators of silver, zinc, copper, and nickel than mussels, while the latter appear to be better concentrators of lead. East- and Gulf-Coast samples generally exhibited levels of transuranic nuclides or Cs-137 that can be attributed to weapons-testing fallout; one anomalous sample originated near a coastal nuclear-power reactor at Plymouth, Massachusetts. West Coast samples exhibited generally higher concentrations of plutonium, and much higher ratios of Am-241 to Pu-239,240 than found in the other two species, but the source of these transuranics is obscure. These data are strongly suggestive of the hypothesis that mussels and oysters draw radionuclides analyzed from suspended particles rather than from solution in water. The byssal threads of mussels show much greater enrichment of Pu-239,240, and often of Am-241, than soft parts of these organisms. Mussel shells record Am-241:Pu-239,240 ratios usually within a factor of two of ratios found in viscera. Monthly collections at Bodega Head and at Narragansett Bay show systematic but different changes in Pu-239,240 and Am-241 levels in mussels over the periods sampled. It was concluded that varying degrees of pollution in U.S. coastal waters have been indicated by elevated levels of one or more pollutants in bivalves, collected at more than one hundred localities around the United States.

2675. Hodson, P.V., B.R. Blunt, and D.J. Spry. 1978. pH-induced changes in blood lead of lead-exposed rainbow trout (Salmo gairdneri). Jour. Fish. Res. Bd. Canada 35:437-445.

Blood of juvenile rainbow trout exposed to up to 1.0 mg Pb/l in water showed increasing lead concentrations as pH of test water decreased from 10.0 to 6.0. A decrease in pH by 1.0 unit from any reference pH resulted in an increase of blood lead by a factor of 2.1 within 24 hrs. In water with pH range from 6.0 to 9.0, blood Pb levels rose from 0.06-0.11 to 1.0-6.0 mg/l as ambient lead increased from 0.003 to 1.0 mg/l. Since sublethal lead toxicity is related to uptake, results suggest that toxicity increases as pH decreases. Reactions of lead with inorganic constituents of test water were complete within 3 hrs and blood lead was at equilibrium with water lead within 48 hrs. Therefore, at time of blood sampling in the pH experiment, both lead complexation processes in the exposure system, plus lead uptake and release from blood, were at equilibrium.

2676. Jackson, G.A. and J.J. Morgan. 1978. Trace metal-chelator interactions and phytoplankton growth in seawater media: theoretical analysis and comparison with reported observations. Limnol. Oceanogr. 23:268-282.

Effects of trace metal chelators in seawater with Ag, Al, Ba, Ca, Cd, Co, Cr, Cu, Fe, Hg, K, Mg, Mn, Na, Ni, Pb, Sr, and Zn were examined theoretically in terms of equilibrium chemical speciation in seawater, including chemical interactions between all metals; naturally occurring ligands such as SiO_3; added organic chelating agents of various binding strengths and total concentrations; and transfer of trace metals to phytoplankton cell surface. An equilibrium model involving 18 metals and 8 ligands was applied to find the metal species in natural seawater, chelator-amended seawater, and synthetic seawater media. Three mechanisms for enhanced supply of iron via chelation were examined: transport through membrane; ligand exchange at cell surface; and increased supply of iron to cell surface by dissociation of a chelate. None accounted for observed effects of chelator variations on growth rate of phytoplankton. Detoxification of toxic metals via chelation showed a strong correlation between growth rate and free Cu^{2+} computed at equilibrium in solution.

2677. Marquis, R.E., K. Mayzel, and E.L. Carstensen. 1976. Cation exchange in cell walls of gram-positive bacteria. Canadian Jour. Microbiol. 22:975-982.

Relative affinities of cations for anionic sites in isolated bacterial cell walls of 6 species were assessed by displacement of one cation by another. Affinity strength determined was $La^{3+} \gg Cd^{2+} > Sr^{2+} > Ca^{2+} > Mg^{2+} > K^{+} > Na^{+} > Li^{+}$; hydrogen had a higher affinity than all other ions. High affinity was correlated with low mobility of bound ions in an electric field. Cation exchange capacities of cell walls were estimated by completely displacing magnesium from cell walls with Na^{+} or H^{+}. Total magnesium displaced varied from 1.77 mg Mg/g dry wt for *Staphylococcus aureus* to about 12.64 mg Mg/g for *Bacillus megaterium*. Amount of displaceable Mg was inversely related to physical compactness of baterial cell walls. Mg or Ca ions can each neutralize, or pair with, two anionic groups in walls in ion-deficient media; previous work indicated these ions pair with only one group at high ionic strength. Authors suggest that there is flexibility in the arrangement of charged groups in the walls. It was concluded that for cells growing in laboratory media, which generally contain excesses of monovalent over divalent cations, there is a mix of small cationic counterions in walls and monovalent cations may predominate even though the wall has a greater affinity for divalent ions.

2678. McFarlane, G.A., and W.G. Franzin. 1978. Elevated heavy metals: a stress on a population of white suckers, *Catostomus commersoni*, in Hamell Lake, Saskatchewan. Jour. Fish. Res. Bd. Canada 35:963-970.

Mean annual metal concentrations, in ug/l, in two lakes receiving heavy metal fallout from a base metal smelter complex near Flin Flon, Manitoba, were for Mn, 30 in Hamell Lake and 114 in Thompson Lake; for Fe, 59 and 110, respectively; for Cu, 13 and 15; for Cd, 0.6 and 0.1; and for Zn, 245 and 20. White suckers from Hamell Lake showed signs typical of a population under stress, which included increased length and weight, increased fecundity, and earlier maturation, reduced spawning success, reduced larval and egg survival, smaller egg size, and reduced longevity compared with Thompson Lake white suckers. Authors attributed these differences to elevated Cd, Cu, and Zn in Hamell Lake waters, particularly in early spring, a critical period in the reproductive cycle of these fish.

2679. Miller, J.C. and R. Landesman. 1978. Reduction of heavy metal toxicity to Xenopus embryos by magnesium ions. Bull. Environ. Contamin. Toxicol. 20:93-95.

Embryos of the amphibian Xenopus laevis were exposed for 6 days to concentrations of 0.001 to 10.0 mg/l of Cd, Mn, or Pb, or 0.001 to 1.0 mg/l of Hg in solution with 0.0 to 200 mg Mg/l. Deformities observed, with increasing metal ions, included: decreased swimming; reduced eye and body pigment; decreased growth; edema; lack of pigmentation; paralysis; and almost no intestinal coiling. Minimum metal levels which reduced growth and intestinal coiling in 20 mg Mg/l were 1.0 mg Cd/l, 0.5 mg Pb/l, 0.05 mg Hg/l, and greater than the maximum of 10 mg Mn/l tested. Survival of embryos at these concentrations were 59% for Cd, 96% for Hg, and 100% for Pb. Decreasing the ambient magnesium levels from 2.0 to 0.2 mg/l increased mortality and severity of deformities at all concentrations of Cd, Hg, Mn, and Pb used and in controls.

2680. Mirkes, D.Z., W.B. Vernberg, and P.J. DeCoursey. 1978. Effects of cadmium and mercury on the behavioral responses and development of Eurypanopeus depressus larvae. Marine Biology 47:143-147.

Development time from megalops to juveniles for larval estuarine mud crabs was extended in 10 ug Cd/l. Cadmium-exposed specimens reached 100% megalops on day 26 and 100% juveniles on day 44, compared to day 22 for megalops and day 34 for juveniles in controls. Survival of stage I zoeae dropped to 80% in 24 hrs in cadmium and 95% in controls. Increased mortality also occurred for megalops and early crab stages exposed to Cd. Swimming rates were elevated for late zoeal stages exposed to 10 ug Cd/l, while 1.8 ug Hg/l depressed swimming rates of early stages.

2681. Nelson, D.M. and J.J. Goering. 1978. Assimilation of silicic acid by phytoplankton in the Baja California and northwest Africa upwelling systems. Limnol. Oceanogr. 23:508-517.

Rates of silicic acid uptake by natural phytoplankton populations were measured from coastal upwelling regions off Baja California and northwest Africa, using Si-30. Silicic acid uptake in both systems extended below the 1.0% light penetration depth and occasionally to 0.01% light depth, about twice the depth of carbon and nitrogen assimilation, and continued at substantial rates throughout the 24 hr day. Uptake rates of diatoms from stations with lowest near-surface silicic acid concentrations were not shown to be substrate limited. Surface particulate silicon concentrations ranged from 0.45 to 7.2 ug Si/l. Upwelling velocities, nutrient concentrations, and nutrient uptake rates suggest that silicon limitation in the Baja California system was prevented by high rates of silicic acid regeneration resulting from dissolution of diatom silica.

2682. Olson, K.R., K.S. Squibb, and R.J. Cousins. 1978.
Tissue uptake, subcellular distribution, and
metabolism of $^{14}CH_3HgCl$ and $CH_3\,^{203}HgCl$ by
rainbow trout, *Salmo gairdneri*. Jour. Fish. Bd.
Canada 35:381-390.

Distribution of methylmercury (MeHg) by rainbow trout was studied during, a 6 week post-exposure period following a single 24 hr exposure to C-14 H_3HgCl and CH_3Hg-203 Cl. Gills contained 100 ug Hg/kg wet wt, approximately 10 times more MeHg than any other tissue after 24 hr exposure; concentrations were lowest for brain and skeletal muscle, at 1.2 and 0.8 ug/kg, respectively. In 2 wks following exposure, gill MeHg concentrations decreased to 14.6, comparable with most other tissues; methylmercury in most other tissues increased and then decreased during the subsequent 4 wk period. Methylmercury levels in brain, skeletal muscle, and gonad were highest at 6 wks, at 7.0, 7.5, and 18.1 mg/kg wet wt, respectively. Six weeks following MeHg exposure, percent of mercury as inorganic Hg^{2+} increased in gill, kidney, and liver and to a lesser extent in all other tissues except skeletal muscle. Total MeHg was greatest in cytosol fractions and usually comprised 50 to 80% of total tissue mercury. In liver cytosol, a methylmercury binding metallothionein-like species accounted for up to 40% of total methylmercury bound. Hg^{2+}, probably derived from demethylation of methylmercury, was associated with a metallothionein-like protein in gill tissue, but no more than 6% of the total mercury in the soluble fraction was bound. Mercury binding to metallothionein-like proteins in kidney and splenic fractions was minimal in spite of relatively large amounts of mercury in cytosol from these tissues. Authors suggest that metallothionein acts as a binding scavenger for methylmercury and inorganic mercury in fish.

2683. Overnell, J. 1976. Inhibition of marine algal photosynthesis by heavy metals. Marine Biology 38:335-342.

Maximum rates of light-induced oxygen production by marine algae *Attheya decora*, *Brachiomonas submarina*, *Dunaliella tertiolecta*, *Isochrysis galbana*, *Monochrysis lutheri*, *Phaeodactylum tricornutum* and *Skeletonema costatum* were compared when exposed to copper, cadmium, mercury, zinc, and an herbicide. I-50 values (concentrations producing 50% inhibition of photosynthesis) after 15 min incubation ranged from 0.2 to 20.0 mg Hg/l, 1.3 to 4.4 mg Cu/l, and 1.3 to 65.4 mg Zn/l; Cd was considered to be non-toxic to algae. *S. costatum* and *A. decora* were especially sensitive to Cu and Hg ions, while *D. tertiolecta* was insensitive to Hg. It was concluded that *A. decora* is a useful indicator of estuarine water quality.

2684. Pearcy, W.G., E.E. Krygier, and N.H. Cutshall. 1977. Biological transport of zinc-65 into the deep sea. Limnol. Oceanogr. 22:846-855.

Specific activities of zinc-65 (Zn-65:Zn) in pelagic and benthic fishes and crustaceans collected off Oregon were correlated with depth of capture to estimate vertical biological transport rates. About 2 yrs are required for transport of Zn-65 from near-surface to abyssobenthic animals at 1000 m depths. Vertical transport appears to be slower in upper waters, suggesting recycling of zinc within biological communities, and more rapid below 500 m. Long vertical transport times for zinc contrasts with shorter times estimated for transport of Zn and other elements by fecal pellets. Authors suggest that this raises questions about the importance of fecal pellets as a rapid transport mechanism for biologically required materials into the deep sea.

2685. Ramprashad, F. and K. Ronald. 1977. A surface preparation study on the effect of methyl mercury on the sensory hair cell population in the cochlea of the harp seal (*Pagophilus groenlandicus* Erxleben, 1777). Canadian Jour. Zool. 55:223-230.

Effect of ingestion of methylmercuric chloride for 3 months on sensory cell populations in the organ of Corti of four harp seals was determined. Sensory hair cell damage along the length of the cochlea in seals on an oral daily dose of 25 mg

CH_3Hg/kg exceeded damage to seals fed 0.25 mg CH_3Hg/kg daily. Two other seals on 25 mg/kg diets died after 3 to 4 weeks from mercury intoxication. Low level damage occurred to hair cells throughout the length of the cochlea in surviving seals; greatest damage was in the middle cochlear coil. Seals on the high Hg diet had 20-24% sensory cell damage at the upper middle coil, whereas only 4-5% damage was found in seals on the low Hg diet. Damage was confined to the three outer rows of hair cells, especially the outermost row. Authors concluded that lack of specificity and low level damage to sensory hair cells was characteristic of mercury and in contrast to other known ototoxic agents.

2686. Schreck, C.B. and H.W. Lorz. 1978. Stress response of coho salmon (Oncorhynchus kisutch) elicited by cadmium and copper and potential use of cortisol as an indicator of stress. Jour. Fish. Res. Bd. Canada 35:1124-1129.

Serum cortisol levels were elevated within 2 hrs in juvenile coho salmon exposed to 60 to 210 ug Cu/l, as $CuCl_2$, in freshwater. Treatment with up to 12 ug $CdCl_2$/l did not elevate cortisol, even in moribund fish. Stressing salmon with sublethal levels of Cu or handling plus close confinement resulted in a return to prestress levels in cortisol titers. Stress produced similar cortisol elevations in controls, but Cu reduced survival after handling and confinement. Salmon exposed to 15 to 90 ug Cu/l had depressed serum chloride levels when transferred to seawater; all fish exposed to 60 and 90 ug Cu/l died between 40 and 96 hrs after transferral. Cadmium did not influence serum chloride levels or saltwater tolerance. Authors suggest that cortisol levels and other characteristics of stress should not be universally applied as indicators in salmon.

2687. Smith, T.G. and F.A.J. Armstrong. 1975. Mercury in seals, terrestrial carnivores, and principal food items of the Inuit, from Holman, N.W.T. Jour. Fish. Res. Bd. Canada 32:795-801.

Ringed seals Phoca hispida had mean total mercury levels of 27.5 mg/kg wet wt in liver and 0.72 mg/kg in muscle; methylmercury levels were 0.96 mg/kg in liver and 0.83 in muscle. Selenium concentrations were 15.5 mg/kg in liver and 1.1 in muscle. Bearded seals Erignathus barbatus contained 143 and 0.53 mg/kg total Hg in liver and muscle, respectively, and 0.3 mg/kg methyl Hg in liver. Both species showed significant positive correlations of Hg with age and weight. Total mercury in muscle of the trout-like Atlantic char Salvelinus alpinus was 0.05 mg/kg. Arctic fox and sledge dogs, which feed on ringed seals, had total mercury contents of 0.77 mg/kg in liver and 0.32 in muscle of fox and 11.5 and 0.79 mg/kg, respectively, for dogs. Blood Hg levels in local people, whose diet includes principally fish and some seals, have been reported as above average, though not constituting a health risk.

2688. Sullivan, J.F., G.J. Atchison, D.J. Kolar, and A.W. McIntosh. 1978. Changes in the predator-prey behavior of fathead minnows (Pimephales promelas) and largemouth bass (Micropterus salmoides) caused by cadmium. Jour. Fish. Res. Bd. Canada 35:446-451.

Prey vulnerability of fathead minnows to largemouth bass increased significantly at a minimum concentration of 0.375 mg $CdCl_2$/l in acute 24-hr exposure and 0.025 mg $CdCl_2$/l in subacute 21-day exposure. The latter concentration is well below maximum toxicant concentrations reported of 0.037-0.057 mg Cd/l for minnows. Cadmium exposure caused altered behavior patterns, such as abnormal schooling in prey.

2689. Swallow, K.C., J.C. Westall, D.M. McKnight, N.M.L. Morel, and F.M.M. Morel. 1978. Potentiometric determination of copper complexation by phytoplankton exudates. Limnol. Oceanogr. 23:538-542.

Potentiometric copper titrations were done on culture media in which eight algal species, Thalassiosira pseudonana, Ankistrodesmus falcatus, Chlamydomonas sp., Pediastrum sp., Staurastrum gracile, Gloeocystis gigas, Tribonema sp., and Cyclotella cryptica were grown to cell concentrations of 100,000 to 1,000,000 cells/ml. Only G. gigas produced extracellular organic compounds that measurably reduced cupric ion activity in 63.5 ug/l total copper by complexation.

2690. Wobeser, G. 1975. Acute toxicity of methyl mercury chloride and mercuric chloride for rainbow trout (Salmo gairdneri) fry and fingerlings. Jour. Fish. Res. Bd. Canada 32:2005-2013.

LC-50 values for methylmercuric chloride at 24, 48, and 96 hrs were 0.084, 0.045, and 0.024 mg Hg/l, respectively, for fry; and 0.125, 0.066, and 0.042 mg Hg/l, respectively, for fingerlings. LC-50 (24 hr) value for mercuric chloride and fingerlings was 0.90 mg/l. Fingerlings exposed to methylmercuric chloride concentrated mercury in their tissues much more rapidly than those exposed to mercuric chloride. Concentration factors (CF) for tissue over water MeHgCl increased from 36 to 220 as exposure time increased to 96 hrs; maximum mean tissue concentration was 7.9 mg Hg/kg in 0.04 mg MeHgCl/l. CF of $HgCl_2$ was only 1.6 to 3.0 at 24 hrs. Acute toxic action of both compounds was exerted on gills. Mercuric chloride caused severe epithelial necrosis over 108 hrs; methylmercuric chloride exposure resulted in epithelial cell swelling and hyperplasia, a marked increase in number of epithelial cells in mitosis, and terminal epithelial desquamation.

2691. Wobeser, G. 1975. Prolonged oral administration of methyl mercury chloride to rainbow trout (Salmo gairdneri) fingerlings. Jour. Fish. Res. Bd. Canada 32:2015-2023.

Rainbow trout fingerlings were fed rations containing 4.0 to 24.0 mg Hg/kg as methylmercuric chloride over 105 days. Fish receiving 16 and 24 mg/kg had significantly higher blood packed cell volumes than controls. Hyperplasia of gill epithelium was the only morphologic alteration detected. Fish accumulated up to 30 mg Hg/kg in muscle over 14 wks, but no mortality could be attributed to mercury. Authors suggest that trout can tolerate a large body burden of mercury with time.

2692. Wold, W.S.M. and I. Suzuki. 1976. The citric acid fermentation by Aspergillus niger: regulation by zinc of growth and acidogenesis. Canadian Jour. Microbiol. 22:1083-1092.

Citric acid fermentation by fungi is divided into two phases, a growth phase during which cells proliferate but do not accumulate citrate, followed by an accumulation phase during which citrate is produced and reproduction proceeds slowly or not at all. Growth phase was maintained with 64 to 130 ug Zn/l in a low sucrose (0.4 to 0.8%) minimal salts medium; however, growth became limited by zinc deficiency of < 65 ug Zn/l and cells passed into accumulating phase over 48 hrs. Addition of

101 ug Zn/l to accumulating cultures reversed phases to growth. Iron, manganese, copper, and calcium, at concentrations up to 942 ug Fe/l, 274 ug Mn/l, 24 ug Cu/l, and 200 ug Ca/l, had no influence on growth or citrate accumulation over 70 hrs; only zinc appeared to regulate growth-accumulation alternating phases.

2693. Wold, W.S.M. and I. Suzuki. 1976. Regulation by zinc and adenosine 3',5'-cyclic monophosphate of growth and citric acid accumulation in Aspergillus niger. Canadian Jour. Microbiol. 22:1093-1101.

The growth phase-citrate accumulation phase alternative of citric acid fermentation in fungi is controlled by external zinc content. Zinc at 130 ug/l maintained growth of Aspergillus, while levels <6 ug Zn/l signaled transition to the accumulating phase within 50 hrs. Cyclic AMP affected growth and acidogenesis rates of cultures in low but not high zinc concentrations; authors concluded that zinc, not AMP, induced phase transition.

2694. Wong, P.T.S., Y.K. Chau, and P.L. Luxon. 1978. Toxicity of a mixture of metals on freshwater algae. Jour. Fish. Res. Bd. Canada 35:479-481.

Recommended levels of metals for Great Lakes Water Quality Objectives, in ug/l, include 50 for As, 0.2 for Cd, 50 for Cr, 5.0 for Cu, 300 for Pb in Lake Superior, 20 for Pb in Lake Huron, and 25 for Pb in the remaining lakes, 0.2 for Hg, 25 for Ni, 10 for Se, and 30 for Zn. In a mixed-metal solution, however, primary productivity of the diatom, Scenedesmus quadricauda, was reduced to 60-80% of control values in 10% of recommended metal concentrations; productivity decreased to 30-60% in 50% of metal concentrations and to 20-30% in all recommended concentrations. Diatoms were more sensitive to metals than reported values for blue-green and green algae.

2695. Wrench, J.J. 1978. Biochemical correlates of dissolved mercury uptake by the oyster Ostrea edulis. Marine Biology 47:79-86.

Equilibrium concentration factors for dissolved mercury in oyster digestive glands were previously found to be 3-4X higher than in gills. In this study, an analysis of soluble protein showed values of 49,300 mg protein /kg wet wt for digestive glands and 700 mg/kg for gills. Starvation significantly reduced soluble protein level of digestive glands to 31.1 mg/kg and to below detection limits in gills. Differences in concentration factors between gills and digestive glands may be based on a quantitative difference in macromolecular binding sites. However, since Hg^{2+} uptake over 48 hrs in 0.05 mg Hg/l was 9.2 mg/kg wet wt in gills and only 1.7 mg/kg in digestive glands, it appeared that soluble protein content influenced final concentrations but not rates at which equilibrium is reached. Dissolved mercury uptake in isolated gills was inhibited by 5 mM 2-4 dinitrophenol, by the absence of a readily metabolizable substrate such as dextrose in uptake medium, and by 1170 mg K^+/l. Strophanthin G (ouabain), an inhibitor of K^+ transport, at 0.01 mM, caused a significant increase in mercury uptake.

2696. Adams, C.E., Jr., W.W. Eckenfelder, Jr., and B.L. Goodman. 1975. The effects and removal of heavy metals in biological treatment. In: Krenkel, P.A. (ed.). Heavy metals in the aquatic environment. Pergamon Press, New York:277-292.

Authors conclude that quality of effluent from activated sludge and anaerobic treatment processes deteriorates at comparatively low concentrations of copper, zinc, chromium, and lead with no increasing deterioration at higher concentrations. These metals tend to form organometallic complexes at low concentrations with certain essential extracellular constituents, thereby inhibiting normal microbial activities. These complexes absorb onto biological flocs and are partially removed from solution along with precipitated metallic ions. A significant portion of the metals are removed through the treatment process depending on metal, metal concentration, pH, and abundance of microorganisms.

2697. Agadi, V.V., N.B. Bhosle, and A.G. Untawale. 1978. Metal concentration in some seaweeds of Goa (India). Botanica Marina XXI:247-250.

Seventeen species of marine algae from five sites in Goa, India, showed considerable variations in concentrations of Co, Cu, Fe, Pb, Mn, Ni, and Zn. Cobalt ranged from 1.3 to 15.2 mg/kg dry wt, copper from 3.2 to 80.4, iron from 130 to 1800, lead from 3.0 to 197.5, manganese from 25 to 3420, nickel from 0.5 to 39.1, and zinc from 2.8 to 203.9. The role of different seaweeds as indicators of metal pollution is discussed in relation to degree of metal accumulation.

2698. Ahsanullah, M. and G.H. Arnott. 1978. Acute toxicity of copper, cadmium, and zinc to larvae of the crab Paragrapsus quadridentatus (H. Milne Edwards), and implications for water quality criteria. Austral. Jour. Marine Freshwater Res. 29:1-8.

LC-50 (96 h) values for crab larvae were 0.17, 0.49 and 1.23 mg/l for copper, cadmium, and zinc salts, respectively. Larvae were 9X more sensitive to Zn and at least 29X more sensitive to Cd than adults. Larval LC-50 (96 hr) values multiplied by an application factor of 0.01 (as recommended in Australian water quality criteria) results in derived "safe" concentrations, which in the case of copper and zinc are below the stated "minimal risk concentrations" of 10 and 20 ug/l, respectively. In view of the known greater sensitivity of larvae of many taxa to heavy metal toxicity, the validity of using the same application factor for both adult and larval stage is questioned.

2699. Atchison, G.J., B.R. Murphy, W.E. Bishop, A.W. McIntosh, and R.A. Mayes. 1977. Trace metal contamination of bluegill (Lepomis macrochirus) from two Indiana lakes. Trans. Amer. Fish. Soc. 106:637-640.

Bluegill sunfish from two industrially contaminated Indiana lakes were analyzed for cadmium, zinc, and lead. Bluegill from several uncontaminated sites were used to establish background metal concentrations. The highest mean concentrations of Cd and Zn in mg/kg dry wt whole fish were found in Palestine Lake bluegill (3.4 Cd, 220.0 Zn) and the highest mean concentration of Pb was found in Little Center Lake bluegill (6.1). These mean concentrations were significantly higher than background.

2700. Badsha, K.S. and M. Sainsbury. 1978. Aspects of the biology and heavy metal accumulation of Aliata mustela. Jour. Fish Biology 12:213-220.

Feeding habits, growth rate, fecundity and other aspects of the general biology of this marine teleost from the Severn Estuary and the Bristol Channel are reviewed for the period 1974/76. Also, the changes in accumulation of Zn, Pb, and Cd during this time were measured. Concentrations of zinc in eviscerated fish, in mg/kg dry wt, for all collections ranged from 45.0 to 98.1; for lead these values were 8.1-24.5; and for cadmium 1.4-4.2. An attempt was made to relate metal residues in fish to dietary patterns.

2701. Berger, V.Y., V.V. Khlebovich, N.M. Kovaleva, and Y.V. Natochin. 1978. The changes of ionic composition of cell volume during adaptation of molluscs (Littorina) to lowered salinity. Comp. Biochem. Physiol. 60A:447-452.

Changes of water content, volume of inulin space, and Na, K and Mg content in foot muscle and hepatopancreas of gastropod molluscs Littorina littorea, L. saxatilis and L. obtusata acclimated to lowered salinity of 14-16 o/oo were investigated. Molluscs were unable to completely regulate cell volume, hydration level of which increases sharply at the first period of hypotony with partial reestablishment during prolonged acclimation to dilute seawater by 6 to 10 days. During adaptation of L. littorea to lowered salinity, the role of ions, especially K, in cell osmoregulation increases. Potassium is retained in cells of these molluscs; ionic quantity does not decrease even in the first steps of hypotony, when loss of sodium and magnesium occurs.

2702. Billard, R. 1978. Changes in structure and fertilizing ability of marine and freshwater fish spermatozoa diluted in media of various salinities. Aquaculture 14:187-198.

Spermatozoa of marine teleosts (sea bass, Dicentrarchus labrax; sea bream, Sparus auratus) or freshwater teleosts (trout Salmo gairdneri; pike, Esox lucius; guppy, Poecilia reticulata) were diluted in media of different salinities. Motility, morphological changes and fertilizing ability were used to judge effects of such treatments. The medium best adapted to dilution of marine fish sperm was about 20 o/oo S. Sperm motility was increased and prolonged, and fertilization rate significantly improved for sea bass at 0.037 o/oo S. For trout and pike, an extender with about 7 o/oo salinity increased motility time and fertility. After dilution in freshwater, structure of trout spermatozoa was considerably altered, such as rupture of plasma membrane and mitochondrial swelling. When spermatozoa were diluted in the extender, there were no significant structural changes in trout, but alteration occurred in mid-piece of guppy spermatozoon. It was concluded that freshwater or seawater are not the best media for artificial insemination of freshwater or marine fish produced in aquaculture.

2703. Brinckman, F.E., K.L. Jewett, W.R. Blair, W.P. Iverson and C. Huey. 1975. Mercury distribution in the Chesapeake Bay. In: Krenkel, P.A. (ed). Heavy metals in the aquatic environment. Pergamon Press, New York:251-252.

Concentrations of total mercury in sediments, unfiltered seawater, and plankton at 10 stations in Chesapeake Bay are reported. For sediments, concentrations in mg/kg dry wt ranged from 0.04 to 1.12; for water 0.02 to 0.68 ug/l; and in zoo- and phytoplankton from 0.06 to 1.65 mg/kg dry wt. Plankton/water mercury ratios ranged from 570 to 7650.

2704. Bryan, G.W. and L.G. Hummerstone. 1978. Heavy metals in the burrowing bivalve *Scrobicularia plana* from contaminated and uncontaminated estuaries. Jour. Mar. Biol. Assn. U.K. 58:401-419.

Concentrations of Ag, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn were analyzed in clam soft tissues from sites in the Gannel and Camel Estuaries in South-West England. In the Gannel Estuary, which receives wastes from old lead mines, clams contained about an order of magnitude higher concentrations of lead, cobalt, cadmium and zinc than in the Camel Estuary, and higher concentrations of other metals also. Maximum concentrations recorded, in mg/kg dry wt soft parts, from *Scrobicularia* collected from the Gannel were 1.2 for Ag, 14.9 for Cd, 66.0 for Co, 2.2 for Cr, 86.0 for Cu, 1240.0 for Fe, 87.0 for Mn, 11.9 for Ni, 828.0 for Pb, and 2940.0 for Zn. In both populations, less than 50% of the total silver, copper and iron was found in digestive gland. For the other metals over 50% occurred in this organ and, in large Gannel animals, more than 90% of the lead, cobalt, cadmium and zinc, implying that they are chiefly absorbed from ingested sediment. In contaminated Gannel animals, all metal concentrations, with the exception of Mn and Fe, increased with increasing size. The main contrast in the Camel animals concerned the concentrations of cadmium and zinc, which were independent of size. This suggests a possible relationship between the slope of the concentration/size regression and level of contamination, although differences in growth rate may also be involved. When animals were exchanged between the two estuaries, their metal concentrations approached those of the natives very slowly. Even after a year, concentrations of lead, cobalt, cadmium and zinc in the digestive gland were still markedly different from those of native animals. The use of Scrobicularia as an indicator of metal contamination is discussed. It is concluded that Scrobicularia should normally be regarded as a long-term integrator of the chronic type of contamination usually associated with estuarine sediments.

2705. Bryan, G.W. and H. Uysal. 1978. Heavy metals in the burrowing bivalve Scrobicularia plana from the Tamar estuary in relation to environmental levels. Jour. Mar. Biol. Assn. U.K. 58:89-108.

Concentrations of Ag, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn were measured in whole soft parts and digestive gland of Scrobicularia plana over its range of distribution in the Tamar estuary. Four metals (Cu, Fe, Mn, Zn) were analyzed in the individual tissues, including shell. As far as possible, concentrations in animals were related to those in the environment. Seasonal variation, distance from shore, and size of animal have also been considered. Partitioning of metals between the digestive gland and remaining soft tissues suggests that uptake of Cd, Co, Cr, Ni, Pb, and Zn occurs mainly through ingestion of sediments. Generally, more than 75% of these metals were found in digestive gland. This organ contributed less to the total amount of Cu and Ag (30-40%), Mn (51-80%) and Fe (3-20%). Lower values of Mn and Fe were found upstream where the availability of 'soluble' metals to clams was higher. Concentrations of Cd, Co, Cr, Ni, Pb and Zn in whole soft parts increased markedly with size, whereas Fe remained relatively constant and levels of Ag, Cu and Mn decreased. In shell, most of the Mn was incorporated in the matrix, presumably via mantle, whereas appreciable amounts of Cu, Fe and Zn were probably incorporated directly from solution by adsorption. Scrobicularia appears to have potential as an indicator of the availability of metals in estuaries and results for Cu, Fe, Mn, and Zn suggest that there were no important changes in the Tamar estuary between 1969 and 1974.

2706. Bull, K.R., R.K. Murton, D. Osborn, P. Ward, and L. Cheng. 1977. High levels of cadmium in Atlantic seabirds and sea-skaters. Nature 269:507-509.

Cadmium concentrations in mg/kg dry wt were determined in liver and kidney from six species of marine seabirds: fulmar, *Fulmaris glacialis*; shearwater, *Puffinus puffinus*; puffin, *Fratercula arctica*; Leach's petrel, *Oceanodroma leucorhoa*; storm petrel, *Hydrobatus pelagicus*; and razorbill, *Alca torda*. Cadmium in liver ranged from 1.4 (razorbill) to 57.0 (Leach's petrel); for kidney these values extended from 14.6 (razorbill) to 240.0 (fulmar). Sea-skaters of the genus *Halobates* are widely-distributed pelagic marine insects which live at the sea surface and feed on zooplankton trapped at the air-sea interface. Samples of *H. micans* from tropical areas of the Atlantic Ocean contained a mean cadmium concentration of 22.7 mg/kg dry wt (range 0.0-309.0). Although most species of seabirds do not eat large quantities of *Halobates*, at least 2 Pacific species have been proven to eat them; however, authors expect these insects to be among the sources from which storm petrels could obtain Cd. It was concluded that the high Cd concentrations found in seabirds originated from natural rather than anthropogenic sources.

2707. Cardasis, C.A., H. Schuel, and L. Herman. 1978. Ultrastructural localization of calcium in unfertilized sea urchin eggs. Jour. Cell Sci. 77:101-115.

The pyroantimonate technique was employed to identify binding sites for calcium in unfertilized *Arbacia punctulata* and *Strongylocentrotus purpuratus* eggs. Since antimony is non-specific and binds with a variety of cations, the identification of calcium was established by specific chelation with ethyleneglycol tetra-acetic acid (EGTA) and X-ray microprobe analysis. Antimony deposits were observed on the egg's membranes, the plasma, cortical (secretory) granule, pigment granule, smooth-surfaced vesicle, and yolk platelet. Deposits were also observed in the mitochondria, rod-containing vesicles, and the vitelline layer. Two types of yolk platelets were observed: a more numerous electron-opaque platelet which had precipitate along its limiting membrane as well as within the stored-matrix substance, and a less-frequently seen platelet with lower electron opacity which contained precipitate only along its limiting membrane. Deposits were reduced at all sites following exposure of eggs to EGTA either prior to or after osmium-antimonate fixations. Initial fixation in glutaraldehyde followed by postfixation in osmium-antimonate solutions provided better preservation of structure by less precipitation than direct fixation in osmium-antimonate. The organelle sites of calcium binding identified within unfertilized sea urchin eggs may participate in stimulus-secretion coupling and activation of embryogenesis at fertilization.

2708. Cheng, T.C. and J.T. Sullivan. 1977. Alterations in the osmoregulation of the pulmonate gastropod Biomphalaria glabrata due to copper. Jour. Invertebrate Pathology 29:101-104.

Freshwater snails were exposed to 0.06 mg/l of copper, as $CuSO_4$. Wet weights of exposed snails increased with time, while those of controls decreased. Dry weights of both experimentals and controls decreased equally. Finally, the ratio of wet wt to dry wt of experimentals was significantly higher than controls after 24 and 48 hr of exposure. Osmolality of hemolymph of exposed snails was significantly lower than control hemolymph after 12, 24, or 36 hr of exposure. Authors concluded that exposure of B. glabrata to copper resulted in osmotic influx of water into tissues and caused death.

2709. Couch, J.A. 1977. Ultrastructural study of lesions in gills of a marine shrimp exposed to cadmium. Jour. Invertebrate Pathology 29:267-288.

Pathologic black gills of 20 pink shrimp, Penaeus duorarum, exposed to 763 ug/l of cadmium chloride for 15 days were compared with gills of controls. Twelve Cd-exposed shrimp developed black gills. Local as well as extensive areas of cell death and necrosis were found in distal gill filaments of gills from these shrimp. It is proposed that necrosis of specialized epithelial cells and septum cells in black gill filaments and contiguous nonblack gill tissue could cause osmoregulatory, detoxifying, and respiratory dysfunction in crustacea, particularly among individuals undergoing environmental stress.

2710. Davenport, J. 1977. A study of the effects of copper applied continuously and discontinuously to specimens of Mytilus edulis (L.) exposed to steady and fluctuating salinity levels. Jour. Mar. Biol. Assn. U.K. 57:63-74.

Survival and behavior of mussels exposed to discontinuous and continuous copper regimes was investigated in both fluctuating salinity conditions and in constant full strength seawater. Continuous 0.5 and 0.25 mg/l added copper caused damage to mussels within 1-2 days. The LT-50 for 0.5 mg/l Cu was about 2 days; for 0.25 mg/l Cu it was 4-5 days. In full strength seawater, a 6 hr on-6 hr off 0.5 mg/l Cu regime caused no damage in 5 days, because *Mytilus* can detect copper in its environment and close its shell valves to avoid exposure to copper. In fluctuating salinity regimes the timing of copper delivery was extremely important. Animals survived copper delivery occurring at low or falling salinities because of interacting closure responses to copper and low salinities. It is suggested that these results cast doubt upon the usefulness of *Mytilus*, and other animals which possess similar closure mechanisms, for use as a biological pollutant monitor.

2711. Delcourt, A. and J.C. Mestre. 1978. The effects of phenylmercuric acetate on the growth of *Chlamydomonas variabilis* Dang. Bull. Environ. Contamin. Toxicol. 20:145-148.

Exposure to phenylmercuric acetate caused a delay in growth of phytoplankton *C. variabilis*. Lag time before exponential growth increased to 5 days as mercury levels increased to 5.0 ug Hg/l in initial algal populations of 21,000 cells/ml. Algae at lower densities had longer lag times at each phenylmercuric acetate concentration.

2712. Dillon, T.M. and J.M. Neff. 1978. Mercury and the estuarine marsh clam, *Rangia cuneata* Gray. II. uptake, tissue distribution and depuration. Marine Environ. Res. 1:67-77.

During a two-week period, *Rangia* accumulated (by a factor of 1132) Hg^{2+} from solutions containing 30 to 50 ug Hg^{2+}/l; most of the mercury located in gill and mantle tissue. Initial depuration (5 hr) in clean seawater was rapid in all tissues. Between 10 and 192 hours, concentrations of mercury in gill, foot and adductor muscles remained stable while mantle, haemolymph and viscera levels continued to fluctuate in a manner suggesting internal redistribution of mercury. After eight days of depuration, viscera contained the most mercury and appeared to be the only tissue to increase its proportionate share of total tissue mercury. After 15 weeks of depuration, residual mercury in whole clams was about 20% of initial concentrations. Acute decreases in salinity (15 o/oo S to 2 o/oo S) enhanced the ability of Rangia to depurate mercury.

2713. Doi, R. and J. Ui. 1975. The distribution of mercury in fish and its form of occurrence. In: Krenkel, P.A. (ed). Heavy metals in the aquatic environment. Pergamon Press, New York:197-221.

Authors emphasize the present aspects of mercury related environmental pollution in Japan, and Japanese Government countermeasures. "The Japanese Government disregarded for a long time the occurrence of Minamata disease in both Kumamoto and Niigata prefectures and therefore had no basic policy in relation to mercury pollution of the human environment. It has been only in the last few years that the Government has begun to carry out periodical environmental surveys."

"In this regard, the Kumamoto University Minamata Disease Research Group published its findings in relation to the third occurrence of Minamata disease on May 21, 1973, and with it came the possibility that Minamata disease had spread to many other parts of the country. As a result of this pressure, the Government was compelled to begin seriously working out a plan of action in relation to the possibility of pervasive mercury pollution. On June 24 of that year it published guidelines on permissible limits for mercury concentrations in fish along with a tentative schedule of allowable intake of methylmercury tainted fish. Along with this action, on June 25 a decision was made to perform immediate surveys in the water basins in Japan, i.e., in Minamata Bay, Yatsushiro Sea, Tokuyama, Arihama, Mizushima, Himi, Uozu, and the port of Sakata. The results of this survey should be published soon. The government further decided to carry out extensive surveys for mercury, PCB, cadmium, lead, and BHC by the end of this year at 8000 locations throughout Japan."

"In spite of this governmental counteraction there is no reason to expect that the present conditions of environmental pollution in Japanese waters will improve in the near future. Further, there is no reason to believe that the high level of mercury contamination in the Japanese people will be changed in any way simply by the expediency of setting limits on the mercury consumption through guidelines on fish consumption. These guidelines are as follows. 1. Permissible levels for fish are less than 0.4 ppm for methylmercury. Fish containing mercury above these levels cannot be sold. The exception to this rule is in the sale of tuna, marlin, swordfish, and freshwater fish with little marketability. Recently six other species of fish were added to the exception for the reason that the consumption of these species is quite small though these fishes contain mercury higher than the permissible levels. 2. The allowable level of methylmercury intake for an adult of 50 kg of weight is 170 ug/week."

"These limitations and permissible levels have little meaningful significance because most of the fish commonly consumed by the Japanese people are of small to medium size and thus contain mercury levels far lower than indicated in the Government guidelines. Also tuna, marlin, and swordfish are not subject to the application of these governmental standards. The allowable levels of methylmercury intake were determined on the basis of a combination of information derived out of animal experiments with monkeys, allowable intake levels derived from research done by the Kumamoto University Minamata Disease Research Group, and levels of permissible intake published by the World Health Organization. Typical cases of methylmercury poisining will not occur if all of the people can keep strictly to the allowable intake levels, and through this the higher mercury levels in fishermen, sushi workers, and fish retailers would be lowered. But for the general public these guidelines are meaningless, for they will not have any lowering effect on the mercury contamination level in the general population because the daily intake of fish per man is about 100-150 g of small size fish with relatively low mercury levels, which results in the absorption of about 50-70 ug/week of methylmercury."

"Moreover, there have been many instances that make it very difficult for us to believe the statements of the authorities in the central government related to environmental pollution. It is undeniable that the extreme secrecy and endless bureaucracy of the Government have made it difficult to get meaningful information as to basic conditions relevant to environmental pollution in Japan. There were many instances of problems related to restriction on the availability of information in the compilation of this report."

2714. Eganhouse, R.P. and D.R. Young. 1978. *In situ* uptake of mercury by the intertidal mussel, *Mytilus californianus*. Marine Poll. Bull. 9:214-217.

Uptake of mercury in tissues was studied by exposing mussels to waters near a submarine wastewater discharge.

Digestive gland concentrations increased rapidly, from 24.7 ug Hg/kg wet wt to 39.7-62.6 ug/kg after 24 wks. Mercury levels in adductor muscles rose slightly from 22.7 ug/kg wet wt to 31.9-46.4 ug/kg and in gonads from 5.1 ug Hg/kg wet wt to a maximum of 7.4 ug/kg. No correlation with depth was observed. Mussels taken from two uncontaminated stations in California contained 21.1-26.7 ug Hg/kg wet wt in digestive glands, 19.3-28.3 in adductor muscles, and 4.5-6.4 in gonads; specimens from the vicinity of an outfall site contained 62.8 ug Hg/kg wet wt in digestive glands, 61.8 in muscles, and 14.2 in gonads.

2715. Ellgaard, E.G., J.E. Tusa, and A.A. Malizia, Jr. 1978. Locomotor activity of the bluegill *Lepomis macrochirus*: hyperactivity induced by sublethal concentrations of cadmium, chromium and zinc. Jour. Fish Biology 12:19-23.

During a two-week period, locomotor activities of fish in 0.1 and 0.25 mg/l of cadmium were, respectively, 1.5 and 7.8 times that of controls. Fish surviving 0.5 mg/l cadmium, a concentration fatal to 30% in 2 weeks, were less active than controls. Fish in 0.05, 2.4 and 24.0 mg/l chromium were, respectively, 1.2, 3.6, and 6.5 times as active more than controls. Metals apparently effect hyperactive locomotor responses by bluegills in a concentration-dependent relationship.

2716. Eyres, J.P. and M. Pugh-Thomas. 1978. Heavy metal pollution of the River Irwell (Lancashire, UK) demonstrated by analysis of substrate materials and macroinvertebrate tissue. Environ. Pollution 16:129-136.

Macroinvertebrate benthos of the River Irwell are impoverished to an extent that cannot be explained solely in terms of organic pollution. Relatively high dissolved oxygen levels are maintained as a result of turbulence.
Substrate-bound levels of lead, copper, and zinc are higher than an unpolluted river over almost the entire length of the Irwell, and at some sites the contamination is particularly severe. Concentrations in water are very low, but high pH, about 7, leads to rapid precipitation of discharged metals to substrate materials. Metal concentrations in sediment were 24 to 500 mg Cu/kg dry wt, 36 to 13,900 mg Pb/kg, and 110 to 1100 mg Zn/kg; levels in freshwater louse, *Asellus aquaticus*, were 160 to 300 mg Cu/kg dry wt, 150 to 600 mg Pb/kg, and 150 to 200 mg Zn/kg.

In leeches, Erpobdella octoculata, these values were 15 to 55 Cu, 30 to 110 Pb, and 980 to 1600 Zn/kg dry wt. Accumulation ratios in Asellus over substrate reached 2.6 for Cu, 1.1 for Pb, and 0.3 for Zn; in Erpobdella these were 0.5 for Cu, 0.2 for Pb, and 2.2 for Zn. Higher accumulation ratios were obtained in lower ambient metal concentrations.

2717. Fletcher, G.L. 1977. Circannual cycles of blood plasma freezing point and Na^+ and Cl^- concentrations in Newfoundland winter flounder (Pseudopleuronectes americanus): correlation with water temperature and photoperiod. Canadian Jour. Zool. 55:789-795.

A 4-year field program was conducted on flounder to correlate changes in plasma Na^+, Cl^-, and freezing point depression with sea-floor water and sediment temperatures, day length, salinity, depth of capture, and observations on burrowing in sediments. Plasma Na^+, Cl^-, and freezing point depression showed annual cycles with maxima in winter (temperature-1.1 to 1.4 C) and minima in summer (10-14 C). The change in freezing point depression from summer to winter was about 0.65 C; 20% of this was attributable to Na^+ and Cl^- and the remaining 80% to the presence of an 'antifreeze'. Data suggest that plasma 'antifreeze' appeared in November (4-6 C) and disappeared during May (-1.0 to 3.0 C). During winter, flounder were found only in deeper areas of sampling sites and usually buried up to 12-15 cm in sediments which were warmer (0.1 to 0.4 C) than seawater. Plasma Na^+, Cl^-, and freezing point depression of flounder held in the laboratory for 7 days were always significantly lower than the field-sampled fish. Differences between these two groups were greatest during summer, suggesting that effects of 'stress' during capture differ seasonally.

2718. Fletcher, G.L. and M.J. King. 1978. Copper, zinc, calcium, magnesium and phosphate in the gonads and livers of sockeye salmon (Oncorhynchus nerka) during spawning migration. Comp. Biochem. Physiol. 60A:127-130.

On entering freshwater during spawning migration, Ca content in testes increased slightly to 40 mg/kg wet wt, Cu decreased slightly to 0.2, Mg decreased slightly to 150, and Zn decreased to 5.0 mg/kg. Metal concentrations in ovaries were lower in Ca at 550 mg/kg wet wt, lower in Cu at 20, equal in Mg at 550, and lower in Zn at 25 mg/kg in freshwater. Liver metal concentrations, in mg/kg wet wt, after migration were 60 in females and 30 in males for Ca; 100 and 250, respectively, for Cu; 275 and 175 for Mg; and 40 and 50 for Zn. Total ovarian Ca, Mg, and Zn increased during migration while total testicular Zn declined. Authors hypothesize that ovarian Zn and most Ca and Mg was obtained from body stores other than liver, since salmon do not eat during migration.

2719. Garside, E.T., D.G. Heinze, and S.E. Barbour. 1977. Thermal preference in relation to salinity in the threespine stickleback, Gasterosteus aculeatus L., with an interpretation of its significance. Canadian Jour. Zool. 55:590-594.

Thermal preferences were determined in thermal gradients of freshwater and seawater of 32 o/oo for acclimation of 5, 15, and 25 C in seawater. Preferred temperatures increased through acclimations of 5-25 C, with those for freshwater tests being about 2 C lower at each acclimation. Final preferenda were 16 and 18 C for freshwater tests and seawater tests, respectively. Final preferendum in such haloplastic species is defined as the highest obtainable preferendum that equals acclimation temperature. A later series of disjunct preference determinations in approximately isosmotic water (10.5 o/oo) for fish acclimated to 7, 15, and 20 C yielded mean values of 17.7, 18.2 and 18.7 C, respectively. A final preferendum has not been designated since samples were of separate origins. A parallel exists between these responses and the response of this and other haloplastic species in determination of upper lethal temperatures. The immediate cause appears to be differentials in metabolic loading occasioned by osmoregulative stresses.

2720. Giddings, J. and G.K. Eddlemon. 1978. Photosynthesis/respiration ratios in aquatic microcosms under arsenic stress. Water, Air, Soil Pollution 9:207-212.

The ratio of net photosynthesis (P) to total ecosystem respiration (R) usually declines when an aquatic ecosystem is subjected to various types of stress. P/R ratios were measured in 12 80-l microcosms containing water, sediment, and entire biotic communities (dominated by Elodea sp. but also including protozoans, rotifers, copepods, cladocerans, oligochaetes, nematodes, snails and insects) from a shallow pond. P and R were estimated from changes in dissolved O_2 concentrations during the day and night, respectively. After 10 weeks, the microcosms were stressed by the addition of sodium arsenate at concentrations of 0, 0.066, 11.5, and 143.0 mg/l (as As). P/R ranged from 1.0 to 1.4 in all microcosms before arsenate was added. Under stress, both P and R declined in the 11.5 and 143.0 mg/l microcosms, with negative net photosynthesis (i.e., decreases in dissolved O_2 during the day) observed on several occasions. P/R in these microcosms fell to zero or below, returning to 1.0 after three weeks. P/R remained above 1.0 in the 0.066 mg/l and control microcosms. Authors suggest that the P/R response could be used for screening suspected hazardous substances in microcosms, as well as for monitoring natural ecosystems.

2721. Goreau, T.J. 1977. Coral skeletal chemistry: physiological and environmental regulation of stable isotopes and trace metals in Montastrea annularis. Proc. Royal Soc. London B. 196:291-315.

A detailed study has been made of C-13, O-18, calcium, magnesium, aluminum, strontium, and iron contents in coral skeleton deposited during a two-year period. Strong seasonal variations in C-13 and Mg contents have been found, and appear to be linked to changes in growth rate. Oxygen-18 content does not show equilibrium physicochemical temperature effects, and its lack of correlation with C-13 indicates complex metabolic isotope fractionation. Strontium content shows little variation. This difference from Mg is predicted on grounds of biochemical ion transport. Iron is detrital in origin. Measured concentrations of metals, in mg/kg dry wt, ranged from 1148 to 2253 for Mg, < 125 for Al, 347,000-385,000 for Ca, 6300-7160 for Sr, and 363-506 for Fe. Seasonal records of trace constituents in coral skeleton are shown to differ from those predicted by previous investigators, indicating that metabolic effects cannot be ignored in paleoenvironmental interpretation of carbonate skeletal chemistry. Stable isotopes are demonstrated to be useful tools in understanding overall carbon metabolism of photosynthetic calcifying organisms. A model of carbon isotope fractionation is developed, and used to place bounds on the sources of carbon used in photosynthesis and calcification. It is estimated that approximately 40% of the carbon supply is from seawater bicarbonate and 60% from recycled respiratory CO_2.

2722. Hall, A.S., F.M. Teeny, and E.J. Gauglitz, Jr. 1977. Mercury in fish and shellfish of the northeast Pacific. III. spiny dogfish, Squalus acanthias. U.S. Dept. Commerce, Fish. Bull. 75:642-645.

Mean (range) mercury concentration in dogfish shark from the state of Washington were 0.92 mg/kg wet wt in fillets (0.09-2.58), and 0.93 mg/kg wet wt in belly flaps (0.14-2.24), with a positive correlation between mercury content of fillets and fish weight. Mercury levels of most samples exceeded the Food and Drug Administration's action level of 0.5 mg/kg wet wt.

2723. Hansen, N., T.R. Folsom, and W.E. Weitz, Jr. 1978. Determination of alkali metals in blood from North Pacific albacore. Comp. Biochem. Physiol. 60A:491-495.

Concentrations of alkali metals in blood of albacore tuna were, in ug/kg wet wt, 6.2 for cesium, 2.6 for sodium, 2.2 for potassium, 443.2 for rubidium, and 21.5 for lithium. In liver, mean concentration for cesium was 26.7; for sodium, 1.2; and for potassium, 3.2. In muscle, mean concentrations were 37.1 for Cs, 0.4 for Na, and 4.1 for K. Total alkali content was almost constant, while individual alkali metals varied with respect to each other and with specimen wet weight.

2724. Hartman, A.M. 1978. Mercury feeding schedules: effects on accumulation, retention and behavior in trout. Trans. Amer. Fish Soc. 107:369-375.

Rainbow trout, Salmo gairdneri, were exposed to 0.5 and 2.0 mg/kg doses of ethyl-mercury (p-toluene sulfonanilide) "Ceresan" each day for a full year and 2.5 and 10.0 mg/kg doses delivered every 5th day of feeding during the year. A further study extended dose levels from 5.0 to 25.0 mg/kg Ceresan given daily. Exposure to lower doses of mercury for either feeding schedule led to concentrations of mercury in muscle that were similar to the average daily index of dose for as long as 6 months of feeding. Assessment of concentration in muscle at 9 months of feeding showed a breakdown of the effect in all groups except the one receiving 0.5 mg/kg of Ceresan daily. Both dose level and schedules influenced the concentrations of mercury in muscle. Concentrations in excess of 0.5 mg Hg/kg wet wt muscle were observed among trout exposed for 270 days or longer to 0.5 mg Hg/kg diet, or 90 days and longer to trout fed diets containing 2.0 mg/kg or higher. Daily treatment with higher doses of 5.0 through 25.0 mg/kg led to dose-related concentrations of mercury in muscle. Orders of mercury concentration in a variety of other tissues differed significantly and were generally related to dose. Fish receiving 10.0 mg/kg of mercury every 5 days or 5.0 mg/kg or greater doses every day in their feed were unable, with few exceptions, to learn to avoid shock when preceded by a signal-light. However, beyond performance on the learning task, there was no evidence of impairment of general behavior, nor was there any indication of physical debilitation resulting from any treatment. There appeared to be a rapid loss of Hg from selected tissues, although estimates of total body burden of Hg remained high after 6 months on a mercury-free diet.

2725. Harvey, E.J., Sr. and L.A. Knight, Jr. 1978. Concentration of three toxic metals in oysters (Crassostrea virginica) of Biloxi and Pascagoula, Mississippi estuaries. Water, Air, Soil Pollution 9:255-261.

Concentrations of cadmium. lead, and mercury were determined in oysters from 3 Mississippi estuaries in 1973 and 1974 oysters contained mean mercury levels from 0.02 to 0.41 mg/kg wet wt; these apparently reflected the low natural background levels. Lead content ranged from 0.07 to 1.65 mg/kg wet wt in Mississippi oysters comparable to levels in Atlantic coast specimens. Mean cadmium concentration ranged from 0.04 to 0.94 mg/kg, approximately 6.7X lower than Atlantic oysters. There was no statistically significant relation between oyster size and content of Cd, Pb, or Hg.

2726. Hoss, D.E., D.S. Peters, W.F. Hettler and L.C. Clements. 1978. Excretion rate of ^{65}Zn: is it a useful tool for estimating metabolism of fish in the field? Jour. Exp. Mar. Biol. Ecol. 31:241-252.

Experiments were conducted with pinfish, Lagodon rhomboides, and black sea bass, Centropristis striata, to determine the practicality of using loss rate of Zn-65 to estimate metabolic rate of fish under natural conditions. No significant correlations were found between this and oxygen consumption, feeding rate, fish size, or temperature. Restricting fish movement had no consistent effect on zinc loss, nor did elevated levels of inorganic zinc in the diet. Because of the lack of positive results, it was concluded that rate of loss of Zn-65 is not a practical method for estimating field metabolism of fish.

2727. Humphrey, H.E.B. 1975. Mercury concentrations in humans and consumption of fish containing methylmercury. In: Krenkel, P.A. (ed.). Heavy metals in the aquatic environment. Pergamon Press, New York:33.

Certain species of fish from Lake St. Clair contain over 0.5 mg/kg Hg wet wt. Accordingly, the relationship between whole blood total mercury concentrations and human consumption of fish was studied in this and another area of Michigan. Randomly sampled adult residents of Algonac who eat less than 2.7 kg of fish annually from the St. Clair River and Lake St. Clair (noneaters) were contrasted with residents eating 11.8 kg or more of such fish annually (eaters). These were compared with similarly defined noneaters and eaters in South Haven where Lake Michigan fish contained <0.5 mg/kg of mercury. Blood mercury levels of 65 Algonac noneaters averaged 5.7 ug/l and ranged from 1.1 to 20.6 ug/l. Comparative values for 42 South Haven noneaters were 5.2 and 1.6-11.5 ug/l, respectively. Mercury levels for persons who ate fish were higher in both communities. Blood mercury levels for 42 Algonac fish eaters averaged 36.4 ug/l and ranged from 3.0 to 95.6 ug/l. Comparative levels for 54 eaters from South Haven were lower, averaging 11.8 ug/l and ranging from 3.7 to 44.6 ug/l. These data show a direct relationship between quantity of fish consumed and concentration of mercury measured in human blood. Preliminary tests for methylmercury in the same human blood samples indicate relationships similar to those observed for total mercury. Eating of sport fish from the St. Clair waters apparently lead to some absorption of methylmercury, but at lower than known toxic levels.

2728. Iverson, W.P., C. Huey, F.E. Brinckman, K.L. Jewett, and W. Blair. 1975. Biological and nonbiological transformations of mercury in aquatic systems. In: Krenkel, P.A. (ed.). Heavy metals in the aquatic environment. Pergamon Press, New York:193-195.

Mercury-tolerant bacterial isolates, especially Pseudomonas, from Chesapeake Bay waters and sediments were examined for their ability to volatilize mercury from trace concentrations of inorganic and organomercury compounds. All of the nine isolates examined produced metallic mercury primarily. One strain of *Pseudomonas* demonstrated a tolerance to a variety of metals in agar media: 1000 mg/kg of Al^{3+}; 10-50 As^{5+}; 50 Co^{2+}; 10 Cr^{3+}; 50 Hg^{2+}; $<$10,000 Mg^{2+}; 100 Pb^{2+}; 10 Sn^{2+}; 1000 Sn^{+4}; and 10 Te^{+6}.

2729. Jernelov, A. and B. Asell. 1975. The feasibility of restoring mercury-contaminated waters. *In*: Krenkel, P.A. (ed.). Heavy metals in the aquatic environment. Pergamon Press, New York:299-309.

The feasibility of dredging, covering, and other methods to contain or remove mercury-contaminated sediments and effects on biomagnification potential in native freshwater fish populations is discussed.

2730. Katz, M. 1975. The effects of heavy metals on fish and aquatic organisms. *In*: Krenkel, P.A. (ed.). Heavy metals in the aquatic environment. Pergamon Press, New York:25-30.

Author briefly reviews literature on effects of various metals including Cu, Zn, Hg, As, Pb, Se, Fe, Ni, Co, Cr, Cd, Na, Ca, Mg, K, Sr, Ba, Mn, Sn, Al, and Pt on freshwater fish behavior, reproduction, disease, blood chemistry, survival. histopathology and growth. Survival, reproduction, and growth of freshwater insects, crustaceans and gastropods is also reviewed. A bibliography of 29 references is appended.

2731. Krygier, E.E. and W.G. Pearcy. 1977. The source of cobalt-60 and migrations of albacore off the west coast of North America. U.S. Dept. Commerce, Fish. Bull. 75:867-870.

Concentrations of Co-60 in liver of albacore tuna *Thunnus alalunga* caught along the west coast of North America between 1963 and 1969 were determined. Variations in Co-60 content between geographic locations were evident and discussed in terms of fallout from atmospheric tests of nuclear weapons, effluents from nuclear reactors, ocean circulation patterns, biological turnover rates, and migratory routes. Authors concluded that Co-60, unlike Zn-65 and Mn-54 levels, were derived primarily from fallout.

2732. Kumaraguru, A.K. and K. Ramamoorthi. 1978. Toxicity of copper to three estuarine bivalves. Marine Environ. Res. 1:43-48.

Static LC-50 (96 hr) values for copper to *Anadara granosa*, *Meretrix casta*, and *Crassostrea madrasensis* was determined at 25 o/oo S, pH 8.0 and 27 C. Values were 60 ug Cu/l for *A. granosa*, 72 for *M. casta*, and 88 for *C. madrasensis*. Revival rates of bivalves which survived exposure to the LC-50 concentrations for the 96-hr period and were then released in the natural environment were 67% for *A. granosa* and *C. madrasensis*, and 83% for *M. casta*.

2733. Lorens, R.B. and M.L. Bender. 1977. Physiological exclusion of magnesium from *Mytilus edulis* calcite. Nature 269:793-794.

The mussel, which normally secretes low magnesium calcite, incorporates anomalously high amounts of Mg into its calcite shell layer when grown in solutions of higher than normal magnesium content. In normal conditions, *Mytilus* physiologically excludes Mg from its shell-forming fluid. At higher Mg concentrations, ion regulatory systems break down causing a substantial increase in content of Mg coprecipitated into mussel shell calcite.

2734. Lux, F.E., J.R. Uzmann, and H.F. Lind. 1978. Strandings of shortfin squid, *Illex illecebrosus*, in New England in fall 1976. Marine Fisheries Rev. 40:21-26.

Massive strandings of squid were observed at Cape Cod Bay, Massachusetts, during 1976. "With the exception of cadmium and copper, which were somewhat higher in the stranded squid, the results were similar to those for the 1972-73 samples caught farther offshore. It is not known if any significance can be attached to the higher levels of cadmium and copper, since the 1976 samples (stranded squid) were based on the entire animals, compared with mantles only for the 1972-73 samples". There was no apparent increase in mercury.

2735. MacLeod, M.G. 1978. Effects of salinity and starvation on the alimentary canal anatomy of the rainbow trout *Salmo gairdeneri* Richardson. Jour. Fish Biology 12:71-79.

Effects of salinity, starvation and their interactions on the alimentary canal of immature trout was studied. Intestinal and rectal cross-sectional areas and height of intestinal villi increased with salinity. The thickness of none of the tissue layers measured in the intestine and rectum, including columnar epithelium and tunica propria, was influenced by salinity. There was a significant negative correlation between salinity and mucous cell distribution density in both intestine and rectum. In trout acclimated to salinities of 15 o/oo and higher, there was a high incidence of deep depresssions in columnar epithelum. The oesophagus and stomach were not visibly affected by salinity There was a marked decrease in intestinal and rectal cross-sectional area and height of intestinal villi with starvation, except in 32.5 o/oo seawater. Mean intestine epithelial cell height decreased with starvation at 32.5 o/oo. A 48-day period of starvation had little effect on the posterior oesophagus and cardiac stomach.

2736. Mangi, J., K. Schmidt, J. Pankow, L. Gaines and P. Turner. 1978. Effects of chromium on some aquatic plants. Environ. Pollution 16:285-291.

Algal growth was inhibited after 14 days exposure to 10 mg CrO_4^{2-}/l in freshwater. Unicellular Pamella mucosa and Palmellococcus protothecoides declined in cell number; filamentous Oedogonium sp. and Hydrodictyon reticulatum lost weight; and duckweeds Lemna minor and Spirodela polyrrhiza grew fewer new fronds than controls. Plants exposed to 10 mg Cr/l generally accumulated 100 to 5000 mg Cr/kg over 14 days; Palmellococcus accumulated over 1,000,000 mg/kg. Maximum enrichment values in algae of 200 to 500 over medium were reached in lower Cr levels of 0.001 mg/l. Chromium was taken up by dead algae. Heat-killed Oedogonium removed 70-90% of Cr in solution over 6 days.

2737. Marchetti, R. 1978. Acute toxicity of alkyl leads to some marine organisms. Marine Poll. Bull. 9:206-207.

Following the wreck of the Yugoslavian cargo ship "Cavtat" in the Adriatic Sea in 1974 with resultant spillage of alkyl lead compounds, an investigation was conducted to establish the acute toxicities of alkyl lead compounds to representative marine organisms. Concentrations of tetramethyl lead and tetraethyl lead, in ug/l, that reduced oxygen consumption by 50% over 48 hrs in marine bacteria were 1900 and

200, respectively. Photosynthesis decreased 50% in algae, *Dunaliella tertiolecta*, in 1650 and 150 ug/l, respectively. LC-50 (48 hr) values for brine shrimp larvae, *Artemia salina*, were 250 (tetramethyl) and 85 ug/l (tetraethyl). For fish larvae, *Morone labrox*, LC-50 (48 hr) values were 100 and 65 ug/l, respectively. No effect was seen during 48 hrs at tetramethyl lead and tetraethyl lead levels of 900 and 80 ug/l, respectively, for bacteria, 450 and 100 for algae, 180 and 25 for brine shrimp, and 45 and 10 ug/l for fish.

2738. McCarty, L.S. and A.H. Houston. 1977. Na^+:K^+- and HCO_3^- stimulated ATPase activities in the gills and kidneys of thermally acclimated rainbow trout, *Salmo gairdneri*. Canadian Jour. Zool. 55:704-712.

Gill and kidney Mg^{2+}-dependent, Na^+:K^+- and HCO_3^- stimulated ATPase activities were estimated at 25 C and at acclimation temperature in trout acclimated to 2, 10 and 18 C, as were plasma levels of Na, K, and chloride. Sodium and chloride exhibited no significant variation between 2 and 18 C. When assayed at 25 C, Mg^{2+}-dependent and HCO_3^- stimulated ATPase activities did not vary consistently or significantly in relation to acclimation temperature. Under comparable assay conditions both gill and kidney Na^+:K^+-stimulated activities declined at higher acclimation temperatures. Significant increases in all activities were encountered when preparations were incubated at the appropriate acclimation temperature. Results suggest that the branchial Na^+:K^+-ATPase system serves primarily as a high-temperature amplifier of Na uptake, and may contribute little to the maintenance of Na balance in the cold-adapted animal. No evidence of a critical involvement of HCO_3^- stimulated ATPase in ionic regulations was obtained.

2739. Miettinen, J.K. 1975. The accumulation and excretion of heavy metals in organisms. *In*: Krenkel, P.A. (ed.). Heavy metals in the aquatic environment. Pergamon Press, New York:155-162.

Mechanisms and rates of absorption and excretion of heavy metals in fish, molluscs, crustaceans and especially man are briefly reviewed. Examples are listed for Cd, Hg, Pb, Zn, Se with emphasis on biological half-time of mercury compounds in aquatic organisms.

2740. Moller, H. 1978. The effects of salinity and temperature on the development and survival of fish parasites. Jour. Fish Biology 12:311-323.

In brackish water the variety of marine and freshwater parasite species is considerably reduced. The distribution of most marine endoparasites in brackish water is restricted by salinity tolerance of hosts, with most parasite species more tolerant than hosts. The influence of salinity and temperature on nine parasite species has been examined; first stage larvae of *Contracaecum aduncum* (a nematode) develop in 0-32 o/oo salinity; *Cryptocotyle lingua* (trematode) proved to be infective at salinities as low as 4 o/oo. The greatest resistance was found in *Anisakis* (nematode) larvae from herring, *Clupea harengus*, which survived for more than half a year. Parasites in fish intestines appear to be unaffected by changing water salinities, as osmolarity in intestines stays nearly constant. Marine ectoparasites (*Acanthochondria depressa* and *Lepeophtheirus pectoralis*, copepods) survive about three times longer than freshwater species (*Piscicola geometra*, a leech; *Argulus foliaceus*, an arguloid crustacean) when salinity is 16 o/oo. High temperature increases effects of adverse salinities on parasites. There is evidence that none of these ectoparasitic species can develop within 7-20 o/oo salinity.

2741. Munda, I.M. 1978. Trace metal concentrations in some Icelandic seaweeds. Botanica Marina XXI:261-263.

Trace metal concentrations in 11 species of marine algae, 4 of Rhodophyceae and 7 of Phaeophyceae ranged from 0.3 to 11.9 mg/kg dry wt for Co; 1.8 to 8.8, with a high of 80, for Cu; 13 to 130, with maxima of 680, for Mn; and 2.5 to 75.0 mg/kg for Zn. Metal levels varied between species; two *Porphyra* species contained highest values of Cu and Zn. In general, concentrations of Co, Mn, and Zn varied inversely with salinity.

2742. Munda, I.M. and C. Garrasi. 1978. Salinity-induced changes of nitrogenous constituents in *Fucus vesiculosus* (Phaeophyceae). Aquatic Botany 4:347-351.

When marine algae, *F. vesiculosus*, were transferred from water of 32 o/oo S to lower salinity of 5 to 15 o/oo, chemical composition of the thallus was altered. The total amount of nitrogenous compounds was distinctly enhanced with time and salinity reduction, including changes in amino acid pattern. After 33 days in 5 o/oo S water, percent dry wt, ash content, and mannitol content decreased and protein nitrogen increased.

2743. Murray, C.N., M. Hoppenheit, and H. Rade. 1978. Accumulation of americium-243 in selected brackish and marine invertebrates. Helgolander wiss. Meeresunters 31:34-54.

Accumulation of americium in the polychaete worm Nereis diversicolor, the brackish-water amphipod Gammarus duebeni and the harpacticoid copepod Tisbe holothuriae was studied under laboratory conditions over a 10-day period. Large differences in concentration factors occurred for the same organisms, depending upon aging of the contaminated medium. Much higher and more variable values were found when uptake was from freshly contaminated solutions than from those aged up to a week. The interaction of specimens with physico-chemical reactions of americium which appear to take place within the first few days after its introduction into water are considered to be responsible for these differences. Uptake from contaminated water that had been allowed to age in the absence of organisms appears to be unaffected by subsequent conditioning by specimens. Americium concentration factors show a strong tendency to increase with decreasing size of the species, varying from over 1000 for T. holothuriae to about 3 for N. diversicolor. The possibility that the mechanisms regulating the uptake of actinides in different species may depend upon pH is briefly discussed.

2744. Myklestad, S., I. Eide, and S. Melsom. 1978. Exchange of heavy metals in Ascophyllum nodosum (L.) Le Jod. in situ by means of transplanting experiments. Environ. Pollution 16:277-284.

Newly-grown tips of brown algae, A. nodosum, transferred from a metal-impacted locality to an uncontaminated site had cadmium, lead, mercury, and zinc contents similar to local uncontaminated plants after 5 months. Tips contained <1.0 to 2.0 mg Cd/kg dry wt, <3.0 mg Pb/kg, 0.04 to 0.10 mg Hg/kg, and 100 to 140 mg Zn/kg. In older parts of algae, Hg and Zn decreased slightly in the uncontaminated area to 1.0 to 1.4 and 1430 to 2710 mg/kg dry wt, respectively; Cd and Pb remained steady in older sections at 4.0 to 7.0 and 9.0 to 39.0 mg/kg, respectively.

2745. Nagahama, Y., W.C. Clarke, and W.S. Hoar. 1977. Influence of salinity on ultrastructure of the secretory cells of the adenohypophyseal pars distalis in yearling coho salmon (*Oncorhynchus kisutch*). Canadian Jour. Zool. 55:183-198.

Six different types of secretory cells were identified in adenohypophyseal pars distalis of salmon acclimated to fresh- or saltwater. Prolactin cells are markedly more active in freshwater than seawater acclimated fish. Prolactin cells exhibit definite functional activity 3 days after transfer from salt- to freshwater, indicating an osmoregulatory role of prolactin in freshwater. Plasma Na showed a significant decline 6 hr after transfer from seawater to freshwater and after one week, remained lower than in fully acclimated freshwater fish. Corticotropic cells did not appear cytologically different in freshwater and seawater fish. GH cells, the most prominent cells in the proximal pars distalis, appear more numerous and more granulated in seawater fish, suggesting an osmoregulatory involvement in young coho salmon. Putative thyrotropic and putative gonadotropic cells (GTH) can be distinguished by differences in granulation. Only one type of GTH cell is evident with ultrastructural features that differ from those of sexually mature salmon. Stellate, non-granulated cells occur in all regions of the adenohypophysis but more frequently in the prolactin follicles; they are much more prominent in seawater than freshwater fish.

2746. Nakahara, H., T. Iskikawa, Y. Sarai, I. Kondo, and S. Mitsuhashi. 1977. Frequency of heavy-metal resistance in bacteria from inpatients in Japan. Nature 266:165-167.

Frequency of resistance in 564 strains of *E. coli*, 331 strains of *K. pneumoniae*, 787 strains of *P. aeruginosa* and 515 strains of *S. aurens* to Hg, Cd, As and Pb was determined. Frequency of a heavy metal resistance was the same as, or higher than, that of an antibiotic resistance, and many isolates were heavy-metal resistant but drug sensitive. A total of 317 R plasmids with an Hg resistance from Hg-resistant *E. coli* and *K. pneumoniae* (91.1% frequency) were isolated. In addition 297 R plasmids mediated arsenic resistance.

2747. Nakazawa, S. 1977. Development of *Fucus* eggs, as affected by iodine, lithium and nitroprusside. Bull. Japan. Soc. Phycol. 25, Suppl.:215-220.

Eggs from the hermaphroditic marine alga *Fucus evanescens* were cultured with KI, NaI, CaI_2, KCl, KBr, LiCl, 2,4-dinitrophenol, and sodium nitroprusside. Iodine induced giant or multiple rhizoids, but lithium (about 500 mg Li^+/l) counteractively diminished rhizoidal development. Nitroprusside completely inhibited rhizoid formation without affecting cleavage.

2748. Nichols, K.M. and R. Rikmenspoel. 1978. Control of flagellar motion in *Chlamydomonas* and *Euglena* by mechanical microinjection of Mg^{2+} and Ca^{2+} and by electric current injection. Jour. Cell Sci. 29:233-247.

Upon impalement with a microelectrode in a Ca^{2+}-free medium containing 5 mM ATP, a Chlamydomonas cell lost its flagellar activity within 45 sec, and the injection of either positive or negative direct current did not stimulate the flagella to beat after that time. When 3 mM Mg^{2+} was added to external medium, the impaled cell exhibited a flagellar frequency of 22 Hz. With 5 mM ATP and 3 mM Mg^{2+} in a Ca^{2+}-free medium, negative direct electric current inhibited flagellar frequency and positive direct electric current enhanced flagellar activity. The flagella recovered to approximately their characteristic frequency (20 Hz) upon the cessation of current. *Euglena* and *Chlamydomonas* cells were mechanically microinjected with Ca^{2+} or Mg^{2+} ions contained in 1.0 M KCl-filled microelectrodes. In both cells, injection of 0.02 M Ca^{2+} resulted in a decrease in flagellar frequency dependent on amount of Ca^{2+} injected. The frequency decreased to zero Hz upon the injection of 16 x 10^{-14} l in *Euglena* and 3.5 x 10^{-14} l in *Chlamydomonas*. The microinjection of 10 x 10^{-14} l of 0.2 M Mg^{2+} into *Euglena* cells resulted in an approximately 2-fold increase in flagellar frequency. *Chlamydomonas* flagella, which stop beating upon impalement in a Mg^{2+}-free medium, began to beat when the cell was injected with Mg^{2+} ions. The flagella exhibited an average frequency of 16 Hz when injected with 1.5 x 10^{-14} l of 0.2 M Mg^{2+}. The data indicate that an increase in internal Mg^{2+} stimulates flagellar frequency and that microinjection of Ca^{2+} inhibits flagellar motility.

2749. Paskins-Hurlburt, A.J., S.C. Skoryna, Y. Tanaka, W. Moore, Jr., and J.F. Stara. 1978. Fucoidan: its binding of lead and other metals. Botanica Marina XXI:13-22.

A sulphated polysaccharide derived from marine algae *Ascophyllum nodosum* was studied for its ability to bind Ba, Ca, Cd, Co, Cr, Cu, Fe, Ag, Mg, Mn, Ni, Pb, Sr and Zn with specific reference to lead and calcium. Studies were carried out *in vitro* and *in vivo* using rats. Using the efficiency of ion-exchange reactions with divalent cations, the order of preferential binding was established for fucoidan. This polyelectrolyte had the greatest affinity for lead with relatively little binding of calcium. Studies *in vivo* demonstrated a 70% reduction in Pb absorbed by rats when using fucoidan. It was concluded that this naturally occurring non-toxic polyelectrolyte is a suitable binding agent for lead and that the insignificant binding of calcium is an important criteria for biological and clinical application. The high biological activity of this compound depends on position and availability of functional groups for the ion-exchange process, and viscosity of the solution.

2750. Patel, G.B. and L.A. Roth. 1977. Effect of sodium chloride on growth and methane production of methanogens. Canadian Jour. Microbiol. 23:893-897.

Methanobacterium hungatii were not affected by up to 5680 mg NaCl/l; however, growth was inhibited at higher concentrations. Concentrations >890 mg NaCl/l were inhibitory to *M. thermoautotrophicum* and an unidentified methanogen. Optimum growth and methane production occurred at 890 mg/l for the unidentified species.

2751. Paul, M. and R.N. Johnston. 1978. Uptake of Ca^{2+} is one of the earliest responses to fertilization of sea urchin eggs. Jour. Exper. Zoology 203:143-149.

Strongylocentrotus purpuratus eggs accumulate Ca-45 for 10 min following insemination. Although 90% of this uptake occurs after the beginning of the cortical reaction and may represent external binding of Ca to the egg surface coats, there is a brief phase of uptake (0-30 sec) which precedes the cortical reaction and this may represent a Ca flux into eggs.

2752. Pribil, S. and P. Marvan. 1976. Accumulation of uranium by the chlorococcal alga *Scenedesmus quadricauda*. Arch. Hydrobiol. suppl. 49:214-225.

Effect of pH, temperature, uranium concentration, and biomass on algal accumulation of U was examined. Accumulation occurred in two phases; about 60% of 18 mg U/l in solution was removed by algae in the first minute, then uptake equilibrium was reached within 7 hrs. After 6 hours at 20-30 C, maximum accumulation in 9.5 mg U/l, was 29,000 mg U/kg dry wt at pH 5.9 to 6.8; in 18 mg U/l, this was 67,000 mg U/kg. In dilute algal solutions of 30 mg biomass/l, accumulation was much greater, up to 94,400 mg U/kg, than in denser cultures. Uranium concentrations in algae reached 79,000 to 100,000 mg U/kg when water residual levels were 3.5-10.0 and 10.0-35.0 mg U/l. Authors concluded that interpretation of U accumulation is complicated by the variety of uranyl ion forms that occur, by physiological processes of algae, and by the variability of accumulation coefficients due to environmental conditions.

2753. Rice, D.W., Jr. and F.L. Harrison. 1978. Copper sensitivity of Pacific herring, Clupea harengus pallasi, during its early life history. U.S. Dept. Comm., Fish. Bull. 76:347-356.

Embryos and larvae of herring were exposed to copper using a flow-through bioassay system. Embryos were exposed continuously from 12 hrs after fertilization until hatching, and larvae from time of hatching until yolk sac absorption. Embryos were also exposed to 36-hr duration pulses of copper. Pulsed exposures started at 62, 98, or 136 hrs after fertilization. The following measurements were taken as indices of the toxic effects of copper: cumulative mortality, percent hatching, and larval length upon hatching. The onset of mortality of herring embryos continously exposed to copper began 90 hrs after fertilization, with deaths occurring over a short interval thereafter. Significant embryo mortalities occurred at a copper concentration as low as 35 ug/l. Larvae continuously exposed to copper showed significant mortality at 300 ug/l copper, with no delay in onset of mortality. Embryos exposed to 36-hr pulses of copper during different developmental stages showed reduced sensitivity when exposed after the response period. Larvae that hatched from eggs exposed to a 36-hr pulse of copper before the response period grew significantly less than those hatched from eggs exposed during later developmental stages.

2754. Rolfe, G.L. and J.C. Jennet. 1975. Environmental lead distribution in relation to automobile and mine and smelter sources. In: Krenkel, P.A. (ed.). Heavy metals in the aquatic environment. Pergamon Press, New York:231-240.

Differences in concentrations of Pb from freshwater fish, macrophytes, sediments, and benthos collected in 1972-1973 from rural areas and sediments and benthos from urban areas were attributable primarily to lead emissions from automobiles. Stream sediments from urban areas contained about 6X more Pb in the upper 10 cm than sediments from rural areas; for the 10-20 cm fraction this difference was about 7X. Mean concentrations of Pb in aquatic biota from rural compartments, in mg/kg, ranged from 1.8-2.4 for fish, 16.2-24.1 for macrophytes, and 5.4-18.9 for benthos. Urban benthos contained 139.6-518.8 mg/kg.

2755. Rosenberg, R. and J.D. Costlow, Jr. 1976. Synergistic effects of cadmium and salinity combined with constant and cycling temperatures on the larval development of two estuarine crab species. Marine Biology 38:291-303.

Various developmental stages of blue crabs, Callinectes sapidus, were tested in 12 combinations of cadmium (0, 50, and 150 ug/l) and salinity (10, 20, 30, and 40 o/oo) at 25 C. A reduction in survival and a significant delay in development from megalopa to third crab occurred in each salinity in 50 ug Cd/l over about 25 days. Cadmium-induced developmental delay, when compared within each salinity regime, was most pronounced in salinities normally preferred by Callinectes. However, comparison within each Cd concentration showed similar development rates regardless of salinity. Developmental stages from hatch onwards of mud crabs, Rhithropanopeus harrisii, were examined in 63 combinations of cadmium (0, 50, and 150 ug/l), salinity (10, 20, and 30 o/oo), constant temperature (20 to 35 C), and cycling temperature (20 to 25, 25 to 30, and 30 to 35 C). Cycling temperatures appeared to have a stimulating effect on survival of larvae compared to constant temperatures, both in presence and absence of cadmium. Zoeal larvae were more susceptible to Cd than mepalops. Development was generally prolonged in high Cd and low temperature; salinity effects were variable.

2756. Sanders, J.G. 1978. Enrichment of estuarine phytoplankton by the addition of dissolved manganese. Marine Environ. Res. 1:59-66.

The response of natural phytoplankton over a period of 4 hours to additions of excess Mn up to 1.6 mg/l in an estuary receiving sewage effluent varied with tidal amplitude. During periods of low tidal amplitude, when dissolved organic carbon (DOC) concentrations were high, carbon uptake by phytoplankton was stimulated. When tidal amplitudes were relatively high, carbon uptake was not affected by Mn addition. The link between high DOC concentrations and stimulation suggests that Mn addition either relieves a deficiency in available Mn caused by organic complexation, or complexes organics from sewage effluent which are otherwise harmful to phytoplankton productivity. Sewage effluent entering estuaries can be both beneficial and detrimental to the phytoplankton population. Productivity is increased by the addition of inorganic nutrients but may be depressed by organics in the effluent.

2757. Shapiro, M.A. and D.W. Connell. 1975. Investigations of heavy metals and other persistent chemicals, Westernport Bay, Australia. In: Krenkel, P.A. (ed.). Heavy metals in the aquatic environment. Pergamon Press, New York:247-250.

Investigations conducted on Cu, Pb, Zn, and Cd, in algae, fish, crustaceans, and molluscs from Westernport Bay are briefly summarized.

2758. Siebers, D. and H.-P. Bulnheim. 1977. Salinity dependence, uptake kinetics, and specificity of amino-acid absorption across the body surface of the oligochaete annelid *Enchytraeus albidus*. Helgolander wiss. Meeresunters. 29:473-492.

Enchytraeus can absorb dissolved C-14-labeled amino acids (glycine, L-alanine, L-valine, α-aminoisobutyric acid) and an amino acid mixture from ambient water across the body surface against considerable concentration gradients. Absorption of neutral amino acids is an active process. Results on inhibition of glycine uptake by a variety of low-molecular-weight substances indicate that glycine absorption is highly specific for neutral amino acids and somewhat less for basic amino acids, and is unspecific for non-α-amino acids, acidic amino acids, carbohydrates, and organic acids. Rates of transintegumentary net influx of glycine are nearly identical to C-14-glycine influx, suggesting that only small amounts of amino acids are released, compared with uptake capacity. Glycine uptake is positively correlated to external salinity. In freshwater, glycine absorption is nearly zero; between 10 and 20 o/oo, uptake increases markedly, reaching maximum values at 30 o/oo; these remain almost constant at 40 o/oo. Transport constants and maximum uptake rates increase with rising salinities. Since absorption of glycine and L-valine is susceptible to sodium depletion, similar mechanisms presumably underlie salinity-dependent uptake of amino acids and sodium-dependent solute transport. Oxygen consumption is not significantly modified by different external salinities. Estimates of nutritional profit gained from absorption of amino acids vary between 4 and 15% of metabolic rate for glycine absorption and between 10 and 39% for uptake of an amino-acid mixture, according to external concentrations and salinities.

2759. Sivalingam, P.M. 1978. Biodeposited trace metals and mineral content studies of some tropical marine algae. Botanica Marina XXI:327-330.

Concentrations of trace metals in waters and sediment of Batu Ferringhi, Penang Island, in 1976 and 1977, indicated that almost all levels fall within the category of water-type I (unpolluted). Biodeposited trace metals in one species of Cyanophyta, 9 of Rhodophyta, 4 of Phaeophyta, and 6 of Chlorophyta showed high values compared to the same water-type category in the Oresund, Sweden, area with the exception [illegible] Zn. Metal levels observed, in mg/kg dry wt, ranged from 74 t[illegible] 242,000 for Ca, 4.0 to 16.0 for Cd, trace to 59 for Cr, trace to 50 for Cu, 350 to 15,500 for Fe, 2000 to 110,100 for K, 3100 to 41,000 for Mg, 24 to 320 for Mn, 2000 to 168,000 for Na, 1.7 to 56.0 for Pb, and 14 to 210 for Zn. No significant correlation of biodeposited trace metals among algal groups was observed. Some algal species, though living in unpolluted water-type I, had biodeposited Zn, Cu, and Pb at concentrations above 100, 20, and 10 mg/kg, respectively, which are values only observable in algal species from polluted areas. Concurrent studies on biodeposited concentrations of elements such as Ca, K, Na, Mg, Mn, and P also showed similar trends. It was proposed that certain algal species within the tropical zone could be used as pollution indicators.

2760. Sturesson, U. 1978. Cadmium enrichment in shells of Mytilus edulis. Ambio 7:122-125.

Accumulation of cadmium was measured in periostracum, nacre, and calcitic and calcitic/aragonitic calcium carbonate sections of shells of mussels exposed to various $CdCl_2$ levels. Maximum cadmium levels were found in periostracum and nacre; concentrations rose to 75 mg Cd/kg and 17 mg Cd/kg, respectively, as ambient levels increased to 200 ug/l for up to 50 days. Mussels accumulate more lead, as shown by previous uptake studies, than cadmium in shells under similar conditions.

2761. Suckcharoen, S., P. Nuorteva, and E. Hasanen. 1978. Alarming signs of mercury pollution in a freshwater area of Thailand. Ambio 7:113-118.

Mercury concentrations in the teleosts *Ophiocephalus striatus*, *Mystus nemurus*, *Notopterus chitala*, *Charias macrocephalus*, and *Pangasius pangasius* in 1973 were among the lowest in the world, ranging from 0.002 to 0.30 mg Hg/kg wet wt with a mean of 0.07 in flesh. Aquatic birds, cormorants, herons, and egrets, contained 0.15 to 0.56 mg/kg wet wt, with a mean of 0.27 in pectoral muscle. Mercury in human hair from unpolluted areas was 0.77 to 14.0 mg/kg, averaging 2.3 mg/kg. A local increase was, however, observed in the flesh of the fish *O. striatus* in the vicinity of a recently established Japanese caustic soda factory, where mercury measured 0.32 to 3.6 mg/kg wet wt flesh. Hg accumulation was observed in human hair of males but not females living in the polluted area.

2762. Tilton, R.C. and B. Rosenberg. 1978. Reversal of the silver inhibition of microorganisms by agar. Applied Environ. Microbiol. 35:1116-1120.

Three agar media were tested for their ability to neutralize bacteriostatic effects of silver on *Escherichia coli*. Silver, at 50 ug/l, killed all *E. coli* within 10 min. However, when thioglycolate-thiosulfate reagent was added with agars, initial colony size was larger and only 50% of the cells died in 10 min. Algal growth was equivalent to controls in up to 400 mg Ag/l with tryptone glucose agar. Growth media differed in their neutralizing capacity; non-inhibitory media tryptone glucose agar and Trypticase soy agar showed more neutralizing capacity than eosin methylene blue agar. The neutralizing effect was a function of the soluble component of the media and not of agar itself.

2763. Torma, A.E. 1978. Oxidation of gallium sulfides by *Thiobacillus ferrooxidans*. Canadian Jour. Microbiol. 24:888-891.

Bacterial oxidation of a naturally occurring gallium-bearing chalcopyrite concentrate and a pure synthetic gallium sulfide was investigated at pH 1.8 and 35 C, using a culture of *Thiobacillus ferrooxidans*. This oxidation process may proceed by direct or by indirect bacterial action. Maximum dissolved gallium and copper concentrations were about 2,200 and 40,200 mg/l, respectively. Order of specific rate of oxygen uptake by *T. ferrooxidans* was approximately $CuFeS_2 \geq$ Ga-bearing $CuFeS_2 > FeS_2 > CuS > Cu_2S > Ga_2S_3$.

2764. Wood, J.M. 1975. Metabolic cycles for toxic elements in the environment. A study of kinetics and mechanism. *In*: Krenkel, P.A. (ed.). Heavy metals in the aquatic environment. Pergamon Press, New York:105-112.

Author categorizes selected elements into three groups according to their toxicity: noncritical elements, *i.e.* Na, K, Mg, Ca, Fe, Li, Rb, Sr, Ba, Al, Si; very toxic and relatively accessible elements such as Be, Co, Ni, Cu, Zn, Sn, As, Se, Te, Pd, Ag, Cd, Pt, Au, Hg, Tl, Pb, Sb, Bi; and toxic but very insoluble or very rare elements Ti, Hf, Zr, W, Nb, Ta, Re, Ga, La, Os, Rh, Ir, Ru. The role of bacteria in the mercury and arsenic cycles is emphasized and illustrated.

2765. Azam, F., R.F. Vaccaro, P.A. Gillespie, E.L. Moussalli, and R.E. Hodson. 1977. Controlled ecosystem pollution experiment: effect of mercury on enclosed water columns. II. marine bacterioplankton. Marine Science Commun. 3:313-329.

Effects of 1.0 and 5.0 ug/l added mercury on natural marine bacterioplankton were examined in Controlled Experimental Ecosystems, plastic cylinders containing 1300 m^3 of seawater and its complement of natural biota from Saanich Inlet, British Columbia. Heterotrophic activity, measured as D-glucose assimilation and respiration, was initially inhibited by 1.0 ug Hg/l to less than 1% of the control, followed by a rapid recovery within 5 days to control levels. Bacterial biomass, estimated from adenosine-5'-triphosphate in bacterial size fraction, decreased to 8-40% of controls, but also recovered within 5-7 days. Succeeding bacterial populations showed enhanced mercury tolerance and were also copper tolerant, although no copper additions were made to enclosures. It is suggested that, whereas decrease in bacterial standing stocks and heterotrophic activity is only transient, dominance of mercury- (and copper-) tolerant bacteria in mercury-polluted ecosystems may have implications for the biologically-mediated rate of mercury.

2766. Baldwin, G.F. and L.B. Kirschner. 1976. Sodium and chloride regulation in *Uca* adapted to 175% sea water. Physiological Zoology 49:158-171.

Sodium and chloride regulation in fiddler crabs adapted to 175% seawater showed that turnover rate for both ions averaged 38%/hr. With urine produced at a rate of 0.5% body weight/day, renal losses contributed 0.1% of the total flux for Na^+ and 0.3% for Cl^-. Intestinal route provided approximately 5% of the total influx of both ions assuming complete absorption of all ingested salts. Deletion of Na^+ or Cl^- from the medium reduced efflux of the corresponding ion, an effect associated with exchange diffusion. However, other results indicate such effects could also be due to permeability changes in the absence of Na^+ or Cl^-. Whether or not exchange diffusion occurs, flux ratio analysis indicated that both Na^+ and Cl^- were actively pumped from crabs in 175% seawater.

2767. Baldwin, G.F. and L.B. Kirschner. 1976. Sodium chloride regulation in *Uca* adapted to 10% sea water. Physiological Zoology 49:172-180.

Aspects of Na^+ and Cl^- regulation in fiddler crabs adapted to 10% seawater were examined. Total body turnover rate averaged 8%/hr for Na^+ and 19% /hr for Cl^-. Urine was produced at the rate of 5% body weight/day. Based on the assumption that blood and urine were isotonic, the renal route represented 3-4% of total efflux of both ions. The intestinal route provided a negligible influx of a salt. Deletion of Na^+ from the medium caused little change in efflux of this ion. Depletion of Cl^- medium caused approximately 50% reduction in Cl^- efflux; however, Na^+ efflux was also reduced in Cl-free medium. Flux ratio analysis indicated that both Na^+ and Cl^- were actively absorbed by fiddler crabs in dilute seawater.

2768. Beers, J.R., M.R. Reeve, and G.D. Grice. 1977. Controlled ecosystem pollution experiment: effect of mercury on enclosed water columns. IV. zooplankton population dynamics and production. Marine Science Commun. 3:355-394.

Taxonomic composition and abundance of total zooplankton populations contained in three 1300 m^3 enclosures (Controlled Experimental Ecosystems or CEEs) in Saanich Inlet, British Columbia, Canada, were studied over a 72 day period from May to July, 1976; inorganic mercury was introduced at nominal concentrations of 5.0 and 1.0 ug/l into CEE 5 and CEE 1, respectively. Immediately following mercury addition, zooplankton populations declined in CEE 5, but the control and CEE 1 remained relatively similar in total numbers and proportional taxonomic composition. In the two latter CEEs, large increases of herbivores occurred as a consequence of nutrient additions and lack of predator pressure. CEE 5 populations showed slight increases, but different dominant forms. The original decrease and failure of copepods *Pseudocalanus* and *Acartia* to subsequently increase their populations rapidly were attributed to direct effects of mercury, although food quality may have affected some of the observed population fluctuations. When mercury level had subsided in CEE 5, some protozoan taxa with short generation times equalled or exceeded the abundance attained in the other CEEs. As a consequence of the few predators present and the correspondingly low mortality of copepod developmental stages, it was possible to compute the production of *Pseudocalanus* and *Acartia*, the two copepods comprising the bulk of the mesoplankton. For CEE 1 and the control at least 29% and 18%, respectively, of the primary production apparently was converted to the next higher trophic level.

2769. Bengtsson, B.-E. 1977. Accumulation of cadmium in some aquatic animals from the Baltic Sea. Ambio, Spec. Rept. 5:69-73.

Salinity is an important modifying factor in accumulation of cadmium in freshwater minnows, *Phoxinus phoxinus*, and marine gobies, *Pomatoschistus minutus*. In 50 ug Cd/l, minnows accumulated 3.0 mg Cd/kg dry wt by 10 days and 12 mg Cd/kg by 24 days in freshwater; this was 6-10X higher than accumulation in 50 ug Cd/l in 7.2 o/oo S. Minnows contained 8.0 mg Cd/kg after 10 days and 17 mg/kg after 24 days when exposed to 300 ug Cd/l in freshwater. Mean cadmium content in minnows exposed to 50 ug Cd/l for 10 days ranged from 2.0 mg Cd/kg dry wt in freshwater to 1.5 mg Cd/kg in 25 o/oo S. Shrimp, *Leander adsperus*, took up 2X more cadmium at 15 C compared to 6 C. After 35 days in 100 ug Cd/l, shrimp whole body levels were 75 mg Cd/kg dry wt in 15 C water and about 37 mg Cd/kg in 6 C. When mortality occurred in cadmium exposed groups of bleaks, *Alburnus alburnus*, accumulation patterns based on surviving fish was confusing compared to experiments where no mortality occurred. Moribund fish contained elevated whole body cadmium concentrations of 125 to 225 mg Cd/kg dry wt in 25 mg Cd/l for up to one week. Consequently, with mortality, the highest water concentrations of cadmium produce a strong selection among individuals. Author concludes that it might be misleading to base an opinion of pollution load on a fish population, unless the magnitude of a direct (pollutant itself) or indirect (*i.e.* selective predation) mortality caused by the pollutant is known.

2770. Bohn, A. and B.W. Fallis. 1978. Metal concentrations (As, Cd, Cu, Pb and Zn) in shorthorn sculpins, *Myoxocephalus scorpius* (Linnaeus), and Arctic char, *Salvelinus alpinus* (Linnaeus), from the vicinity of Strathcona Sound, Northwest Territories. Water Research 12:659-663.

Mean metal levels determined in sculpin from near Strathcona Sound prior to industrial activity were: for As, 40 mg/kg dry wt in muscle and 81 mg/kg in liver; Cd, 1.4 in muscle and 4.1 in liver; Cu, 4.1 in muscle and 7.6 in liver; Pb, 0.3 in liver; and Zn, 43 in muscle and 100 in liver. In landlocked char, concentrations were: for As, 0.5 mg/kg dry wt in muscle and 0.7 mg/kg in liver; Cd, 2.0 in liver; Cu, 2.4 in muscle and 87 in liver; Pb, 0.4 in liver; and Zn, 23 in muscle and 130 in liver. Concentration of arsenic in both muscle and liver from sculpins displayed a positive correlation to body weight over the entire size range, and substantially exceeded the maximum recommended level for arsenic of 5.0 mg/kg wet wt in marine animal products established by the Canadian Food and Drug Directorate. Concentrations of Cd, Cu, Pb, and Zn were either not correlated to body weight or the data were non-linear. No correlation between metal concentrations and body weight was found in Arctic char.

2771. Bruland, K.W., G.A. Knauer and J.H. Martin. 1978. Cadmium in northeast Pacific waters. Limnol. Oceanogr. 23:618-625.

Northeast Pacific water was collected by five different methods and the Cd in it was preconcentrated by both chelex-ion exchange and chelation-organic extraction techniques. All sampling and preconcentration methods yielded essentially the same data. Cadmium was significantly correlated with phosphate and nitrate at all depths and it appears that the resulting equations, ng Cd/l = -3.6 + 34.9 (umol PO_4/l) and ng Cd/l = 5.1 + 2.45 (umol NO_3/l), can be used to predict oceanic Cd values. Cadmium concentrations are lowest in nutrient-depleted surface waters (4.5 ng/l) and greatest (125 ng Cd/l) at the depths of the PO_4 and NO_3 maxima. Hence, Cd has one of the highest deep enrichments:surface depletion ratios ($\approx$30) yet observed. Cadmium and phosphorus are also correlated in microplankton, and it is apparent that these organisms and their organic remains are a dominant factor in the biogeochemical cycling of this element.

2772. Bursey, C.R. 1978. Temperature and salinity tolerance of the mole crab, *Emerita talpoida* (Say) (crustacea, anomura). Comp. Biochem. Physiol. 61A:81-83.

Adult crabs were subjected to 25 temperature-salinity combinations within the range of 5-35 C and 15-65 o/oo S. *E. talpoida* tolerated 15-65 o/oo salinity at 20 C and below throughout 15 hr trials. Optimum salinity for survival at stressful temperatures was 40 o/oo; survival time was 6 hrs at 30 C and 2 hrs at 35 C. Crabs transferred directly from one salinity to another experienced changes in osmoconcentration toward that of the new salinity over 3 hrs. Temperature modified the rate of change toward the experimental salinity.

2773. Button, K.S. and H.P. Hostetter. 1977. Copper sorption and release by *Cyclotella meneghiniana* (Bacillariophyceae) and *Chlamydomonas reinhardtii* (Chlorophyceae). Jour. Phycology 13:198-202.

Initial Cu^{2+} sorption by *C. meneghiniana* (Cu^{2+} sensitive) and *C. reinhardtii* (Cu^{2+} resistant) was rapid in the first 5 min of Cu^{2+} incubation with little sorption after 2 hr. On a cell to cell basis, *Cyclotella* sorbed about 5X more Cu^{2+} from the medium than *Chlamydomonas*. In media with EDTA, *Cyclotella* and *Chlamydomonas* cells sorbed 1.33 and 0.28 ug $Cu^{2+}/10^6$ cells, respectively, after 6 hr in 0.3 mg Cu^{2+}/l. Proportionally similar quantities of Cu^{2+} were sorbed when cells were Cu^{2+} incubated in media containing citrate or filtered lake water. Cleaned cell walls of *Cyclotella* sorbed little Cu^{2+} (0.11 ug/10^6 cells) as compared to living cells (1.11) in 3 hr. Therefore, in living *Cyclotella* most Cu^{2+} taken up is absorbed by protoplasm or perhaps by the organic layer surrounding the silica wall. Cleaned cell walls of *Chlamydomonas* sorbed 0.22 ug $Cu^{2+}/10^6$ cells and living *Chlamydomonas* cells sorbed 0.16. This indicates that most of the Cu^{2+} sorbed by *Chlamydomonas* cells remained bound to the cell wall and probably did not readily enter into protoplasm. When placed in Cu^{2+} free medium after Cu^{2+} incubation, *Cyclotella* and *Chlamydomonas* cells released 46 and 59%, respectively, of the Cu^{2+} sorbed.

2774. Cox, J.A., L. Kohler, and G. Benzonana. 1976. Ionic composition and distribution of myogen proteins in the tail muscle of fresh water crayfish. Comp. Biochem. Physiol. 53B:101-105.

Ionic concentrations in myogen of tail muscle of crayfish *Astacus* (*pontastacus*) *leptodactylus leptodactylus* were, in mg/kg wet wt 510 Na, 44 Ca, 230 Mg, 1640 K, 2.3 Cu, and 15 Zn; Na and Ca were predominantly extracellular and the others intracellular. Haemolymph concentrations were, in mg/l, 3100 Na, 430 Ca, 43 Mg, 100 K, 23 Cu, and 0.6 Zn. One of several major myogen proteins binds most of the calcium present in myogen and appears to be different from Ca-binding proteins described previously in muscle.

2775. Danil'chenko, O.P. 1977. The sensitivity of fish embryos to the effect of toxicants. Jour. Ichthyology 17:455-463.

Effects of triethyl stannic chloride (TESC), tripropyl stannic chloride (TPSC), dimethyl stannous chloride (DMSC), and other toxicants on various developmental stages of perch *Perca fluviatilis*, ruffe *Acerina cernua*, loach *Misgurnus fossilis*, and sturgeons *Acipenser guldenstadt*, *A. stellatus*, and *A. nudiventris* were investigated. For all species, organotin compounds were most toxic and larval stages appeared to be the most sensitive. Maximum concentrations of individual toxicants tolerated by larvae of loach were 0.1 mg/l for TESC, 0.01 for TPSC, and 100.0 for DMSC; for sturgeon larvae these were 0.01 mg/l for TESC and 0.000001 mg/l for TPSC.

2776. Davies, P.H., J.P. Goettl, Jr. and J.R. Sinley. 1978. Toxicity of silver to rainbow trout (Salmo gairdneri). Water Research 12:113-117.

Mean LC-50 (96 hr) values of silver and rainbow trout were 6.5 ug/l and 13.0 ug/l in soft water of approximately 26 mg $CaCO_3$/l hardness and in hard water of 350 mg/l hardness, respectively. The long-term "no observed effect" concentration for silver nitrate was bracketed by 0.09 and 0.17 ug Ag/l after 18 months exposure in soft water. No mortalities attributable to silver occurred at 0.09 ug Ag/l, whereas 17% mortality occurred at 0.17 ug/l. The "no effect" concentration does not reflect possible effects of silver on spawning behavior or reproduction, since female rainbow trout will not generally reach sexual maturity before 3 yrs. At concentrations of $\geq$0.17 ug/l, silver caused premature hatching of eggs and reduced growth rate in fry. In one experiment, the eggs were completely hatched within 10 days of exposure; control eggs completed hatching after 42 days. Prematurely-hatched fry were not well developed and frequently died; growth rate of surviving fry wa- greatly reduced.

2777. Dooris, P.M. and D.F. Martin. 1978. Effects of chelated iron on the growth of two species of Vallisneria Water Resources Bull. 14:1088-1093.

Iron, added as (Fe-EDTA)$^-$, was found stimulatory to V. spiralis at a concentration of 0.05 mg/l. (Fe-EDTA)$^-$ had no effect upon growth of V. neotropicalis as measured by changes in dissolved oxygen and dry weight. Results are compared with those derived from similar studies with Hydrilla verticillata and Egeria densa. The growth response of Vallisneria to various iron concentrations compared with that of Hydrilla reveals that the higher iron concentrations which stimulated Hydrilla (0.10, 0.15 mg/l) were inhibitory to V. spiralis. Under some conditions Vallisneria exhibit higher survival where compared to other aquatic plants such as Hydrilla as a function of iron content of waters.

2778. Freeman, R.F.H. and T.J. Shuttleworth. 1977. Distribution of intracellular solutes in Arenicola marina (polychaeta) equilibrated to diluted sea water. Jour. Marine Biol. Assn. U.K. 57:889-905.

Measurements were made of sodium, potassium and chloride in tissues of A. marina equilibrated to 100%, 50%, 35%, 30%, and 25% seawater. Summed amounts of these ions in cells remained approximately constant in dilutions down to 30% seawater, and decreases in concentration were due to increased hydration of cells. Worms in 25% SW accumulated intracellular ions nearly 15% above worms in full-strength seawater; their intracellular concentration was greater than predicted from the change in water content. The percentage contribution which these ions make to the total intracellular concentration increased from 40% in 100% SW to 61% in 25% SW. Authors concluded that restriction on entry of water into cells in dilute media is by loss of solutes which were not measured in this investigation, and that failure of cell volume regulation in 25-30% seawater is associated with a maximal loss of 52% of these unmeasured solutes.

2779. Gould, E. 1977. Alteration of enzymes in winter flounder, Pseudopleuronectes americanus exposed to sublethal amounts of cadmium chloride. In: Vernberg, F.J., A. Calabrese, F.P. Thurberg, and W.B. Vernberg (eds.). Physiological responses of marine biota to pollutants. Academic Press, New York:209-224.

Adult flounder were exposed for 60 days at 3-6 C to 0, 5, or 10 ug Cd^{2+}/l. At 60 days fish were removed, and samples of kidney and hemopoeitic tissue analyzed for enzyme activity. Significant decreases were observed at 10 ug Cd^{2+}/l in activities of leucine aminopeptidase, carbonic anhydrase and glucose-6-phosphate dehydrogenase. Author concludes that sublethal amounts of cadmium affect enzymes whose catalytic activity is largely dependent upon allosteric mechanisms.

2780. Grice, G.D. and D.W. Menzel. 1978. Controlled ecosystem pollution experiment: effect of mercury on enclosed water columns. VIII. summary of results. Marine Sci. Commun. 4:23-31.

Natural marine communities of bacteria, phytoplankton, zooplankton, and chum salmon were exposed to 1.0 and 5.0 ug/l mercury for 72 days in 1300 m^3 plastic enclosures. Results of productivity, growth, abundance, and taxonomic distribution of plankton, and growth and Hg tissue accumulation of salmon are summarized.

2781. Hain, J.H.W. 1975. The behaviour of migratory eels, Anguilla rostrata, in response to current, salinity and lunar period. Helgol. wiss. Meeresunters. 27:211-233.

Behavior of migratory silver eels and immature yellow eels, Anguilla rostrata, was studied in a choice-chamber apparatus. Silver eels reversed their response to a positive rheotaxis when saltwater was introduced into the tank. Rheotaxis and the salinity response are proposed as an effective orientation mechanism in the seaward migration of the silver eel. Responses are anticipatory in nature and are thought to be only part of a sequential arrangement of orientation behaviors. Yellow and silver eels in heterogenous samples showed similar rheotactic responses in freshwater but were segregated by response in saltwater. The non-orientation of the yellow eels in the freshwater-saltwater choice suggests that it is the response to salinity which contains yellow eel in its feeding habitat and later guides the silver eel away from it. Perception of saltwater by silver eels is olfactory.

2782. Hanson, R.C., D. Duff, J. Brehe, and W.R. Fleming. 1976. The effect of various salinities, hypophysectomy, and hormone treatments on the survival and sodium and potassium content of juvenile bowfin, Amia calva. Physiological Zoology 49:376-385.

Young-of-the-year bowfin were tested for salinity tolerance and effects of hypophysectomy on survival. These fish lived well in 24% seawater but promptly failed when transferred into 30% seawater. They retained Na^+ well, but lost whole-body K^+ rapidly, in both distilled water and dilute seawater. It is suggested that K^+ loss may largely reflect the effect of starvation on young rapidly growing animals. Hypophysectomy caused an increase in Na^+ permeability which was reversed by ovine prolactin. This hormone, however, caused a marked drop in serum protein levels. While ovine prolactin did prolong survival somewhat, it would not do so indefinitely. This hormone was highly toxic when injected into intact animals. Bovine prolactin and Amia pituitary injection were the most effective treatments for prolonging survival of hypophysectomized bowfins.

2783. Harding, J.P.C. and B.A. Whitton. 1978. Zinc, cadmium and lead in water, sediments and submerged plants of the Derwent Reservoir, Northern England. Water Research 12:307-316.

A partial budget is presented of Zn, Cd, and Pb entering the Derwent Reservoir. Mean levels in water upstream of inflow are: Zn, 0.216 mg/l; Cd, 0.003; and Pb, 0.065. Levels after passage through the 4.1 km^2 reservoir declined by 70.3% for Zn; Cd, 98.3%; and Pb, 89.2%. Most of these metals are deposited in sediments, with mean values of: Zn, 1035 mg/kg, Cd, 13; and Pb, 827. Lead, a higher percentage of which occurs as particulate material, is deposited more rapidly than zinc; this effect is especially obvious when streaming of colder water along the bottom of the reservoir takes place at the time of floods. Sediment levels of Ca and Ag were correlated with Pb; Zn, Ni, Cu, and Co were correlated with Fe; Cd showed only weak correlations with Pb, Fe, and Cu, a strong relation with Ni, but none with Zn. Macroscopic plants are only occasional in this reservoir, due perhaps in part to heavy metal loadings. Of the two most common submerged species, Nitella flexilis probably accumulates almost all of its metal content directly from water. However, data suggest that sediments are a source of some heavy metals accumulated by Glyceria fluitans. Metal content in Nitella decreased from >1750 to 250-500 mg/kg dry wt for Zn, from >21 to 6.9-9.0 for Cd, and from >875 to 0-125 for Pb as distance from inflow increased. Lead decreased in Glyceria from >175 to 0-125 mg/kg dry wt in the same pattern.

2784. Harrison, W.G., E.H. Renger, and R.W. Eppley. 1978. Controlled ecosystem pollution experiment: effect of mercury on enclosed water columns. VII. inhibition of nitrogen assimilation and ammonia regeneration by plankton in seawater samples. Marine Science Commun. 4:13-22.

Additions of mercury at concentrations from 1.0 to 100 ug/l to natural samples of coastal seawater caused inhibition of nitrate and ammonia assimilation by phytoplankton, and ammonia regeneration by bacteria and/or microzooplankton down to 25 to 50% of control rates in 24-48 hr experiments. Phosphate uptake was similarly reduced. Synthesis of nitrate reductase was stimulated by low concentrations of mercury and inhibited by higher concentrations of 5.0 ug Hg/l.

2785. Heinis, J.J., L.R. Beuchat, and F.C. Boswell. 1978.

Antimetabolite sensitivity and magnesium uptake by thermally stressed *Vibrio parahaemolyticus*. Applied Environ. Microbiol. 35:1035-1040.

Metabolic inhibitors were added to a culture medium inoculated with thermally stressed bacteria *Vibrio parahaemolyticus* to obtain information pertaining to biosynthetic processes required for recovery from heat damage. Ribonucleic acid and protein syntheses, in addition to membrane repair, were required during recovery of injured cells. Neither nucleic acid nor Mg^{2+} leakage was noted while cells were subjected to heat stress. Studies showed that Mg^{2+} was taken up by cells of *V. parahaemolyticus* during the first 30 min after thermal treatment, indicating a possible increased requirement for Mg^{2+} for membrane or ribosome stability and repair.

2786. Hewett, C.J. and D.F. Jefferies. 1978. The accumulation of radioactive caesium from food by the plaice (*Pleuronectes platessa*) and the brown trout (*Salmo trutta*). Jour. Fish Biology 13:143-153.

Patterns of accumulation of Cs-137 from food by tissues and organs of a marine flounder and a freshwater trout were compared. Mean ratios of Cs-137 accumulation in plaice from food over accumulation from water ranged from 0.65, 0.65, and 0.46 in gut, liver, and gill, respectively, over 40 days, to 0.34 in skin. The mean ratio of all tissues excluding liver and gut was 0.41. Accumulation ratios in trout ranged from 0.81, 0.75, and 0.75 in gut, liver and kidney, to 0.57 and 0.55 in gill and skin; overall mean excluding gut was 0.66. Biological half-life of Cs-137 in whole plaice was 57.9 days, ranging from 139.0 days in muscle to 9.6 days in kidney. Cs-137 half-lives in trout were 68.8 days in whole fish, a maximum of 126.4 days in muscle, and a minimum of 21.4 days in gills. Rate constants were similar to those obtained from the accumulation from water studies. Plaice gut and liver had an 11% increase and trout gut a 6% increase in their share of Cs-137 intake arising from accumulation from food, compared with accumulation from water. These increases were balanced by decreases in the muscle share of the intake. The overall absorption of Cs-137 from food was 42% for plaice and 67% for trout.

2787. Howarth, R.S. and J.B. Sprague. 1978. Copper lethality to rainbow trout in waters of various hardness and pH. Water Research 12:455-462.

LC-50 (96 hr) values of total dissolved copper to trout varied from 20 ug/l in soft acid water to 520 ug/l in hard alkaline water, in hardness ranging from 30 to 360 mg/l as $CaCO_3$ and pH from 5 to 9. The 3-dimensional response surface was complex; an increase in hardness usually made copper less toxic. A good prediction of copper LC-50 at usual combinations of hardness and pH was given by the equation:

LC-50 = antilog (1.933 + 0.0592 P_T + 0.4912 H_T + 0.4035 P_TH_T + 0.4813 $P_T{}^2$ + 0.1403 $H^T{}_2$) where H_T = hardness and P_T = pH.

The transformed variables are:

$$H_T = \frac{\text{Log}_{10}\ \text{hardness} - 2.01671}{0.62308}$$

$$P_T = \frac{\text{pH} - 7.0}{2.0}$$

Trout of 10 g wt were 2.5X more resistant than 0.7 g trout regardless of hardness and pH combination, and effect was predictable by an equation LC-50 = Constant x Weight $^{0.348}$. Ionic copper (Cu^{2+}) and two ionized hydroxides ($CuOH^+$ and $Cu_2OH_2{}^{2+}$) seemed to be the toxic species of copper, since they yielded the smoothest response surface with the best fit to measured LC-50's. The sum of these ions produced LC-50's ranging from 0.09 ug Cu/l in soft alkaline water to 230 ug/l in hard acid water. The ions were different in relative toxicity. or became more toxic at high pH, or both

2788. Jacobs, R. and O. Lind. 1977. The combined relationship of temperature and molybdenum concentration to nitrogen fixation by Anabaena cyclindrica. Microbial Ecology 3:205-217.

The joint effects of growth temperature, incubation temperature, and molybdenum concentration on nitrogen fixation rate of Anabaena cylindrica were determined. The nitrogen-fixation response to increased molybdenum concentration varied among three growth temperatures (15, 23, and 30 C). The pattern of rate change was similar within a growth temperature but increased overall in magnitude with the three incubation temperatures (also 15, 23, and 30 C). The maximum rate of nitrogen fixation occurred at 30 C regardless of previous growth temperature. The minimum molybdenum concentration necessary to yield substantial acetylene reduction varied with growth temperature: at 15 C, 15 ug Mo/l was effective; at 23 C, less than 5 ug/l was effective; and at 30 C, 50 ug/l was effective.

At all three growth temperatures, increases in molybdenum concentration above the minimum effective concentration produced increases in acetylene reduction. However, at higher molybdenum concentrations inhibition of nitrogen fixation occurred.

2789. Jennings, C.D. 1978. Selective uptake of ^{55}Fe from seawater by zooplankton. Marine Science Commun. 4:49-58.

Iron-55 levels in water from the South Pacific Ocean during August and September, 1972, ranged from <0.00003 to 0.00016 pCi/l; concentrations in zooplankton were 0.0004 to 0.004 uCi/kg dry wt. Specific activity ratios of Fe-55 (uCi/kg Fe) between plankton and water from the same locations were about 100, suggesting that zooplankton accumulated Fe-55 in preference to stable iron.

2790. Khlebovich, V.V., G.A. Vinogradov, D.K. Dirin, and T.G. L'vova. 1977. Sodium and calcium metabolism of pink salmon (*Oncorhynchus gorbuscha*) eggs during the first few hours after fertilization in waters differing in their content of dissolved salts. Jour. Ichthyology 17:504-507.

Regardless of Na$^+$ and Ca^{2+} content of incubation waters studied, salmon eggs give up Na$^+$ and accumulate Ca^{2+} during the first few hours post-fertilization.

2791. Koeller, P.A. and G.T. Wallace. 1977. Controlled ecosystem pollution experiment: effect of mercury on enclosed water columns. V. growth of juvenile chum salmon (*Oncorhynchus keta*). Marine Science Commun. 3:395-406.

Growth of juvenile salmon was examined in three 1300 m^3 plastic cylinders (CEEs) moored in Saanich Inlet, British Columbia. After six weeks, growth of salmon in 5.0 ug/l HgCl$_2$ began to decrease, while growth in an initial concentration of 1.0 ug/l was normal compared to controls. Concentrations of mercury in fish muscle were lower during period of reduced growth than earlier in the experiment, when growth appeared normal in all CEEs. Salmon in 5.0 ug Hg/l contained 5.8 mg Hg/kg wet wt after 16 days, 1.0 after 44 days, and 0.8 after 72 days; mercury in fish in 1.0 ug Hg/l and controls decreased from

0.5 to 0.2 and 0.03 to 0.01 mg/kg, respectively, over the same period. There was a decreased abundance of the favored prey items (copepods and decapod and barnacle larvae) in the CEE with the higher mercury concentration. Indirect effects of mercury pollution, such as a decrease in population of organisms at lower trophic levels, may be as important in reduction of fish production as direct toxic effects upon fish.

2792. Koike, I., A. Hattori, and J.J. Goering. 1978. Controlled ecosystem pollution experiment: effect of mercury on enclosed water columns. VI. denitrification by marine bacteria. Marine Science Commun. 4:1-12.

Effects of 5.0 ug/l mercury on denitrification by natural populations of marine bacteria in 1300 m^3 Controlled Experimental Ecosystems (CEE) were investigated over a period of 62 days using N-15 labeled nitrate. Denitrifying activities, i.e. N_2 production, 27 days after mercury addition, were similar in bottom water and in newly formed sediments in a CEE containing 5.0 ug Hg/l and controls. After 62 days, denitrifying activity in Hg CEE sediments exhibited a 6X higher half saturation constant (K_m) for nitrate than control CEE sediments. Apparently a selection for denitrifying bacteria with a high K_m occurs when natural populations of marine denitrifiers are exposed to 5.0 ug Hg/l for 62 days.

2793. Kumar, H.D. and L.C. Rai. 1978. Zirconium-induced precipitation of phosphate as a means of controlling eutrophication. Aquatic Botany 4:359-366.

A potentially promising method of controlling eutrophication by means of zirconium oxychloride, a chemical precipitant for phosphate, is described. Zirconium oxychloride precipitates phosphate and limits algal growth at fairly low concentrations (100 mg/l) within a pH range of 2-11. At 100 mg/l, $ZrOCl_2$ does not seem to be harmful either to algae Chlorella vulgaris after 15 days, or teleosts Heteropneustes fossilis and Clarius sp. after 2 months.

2794. Linko, R.R. and K. Terho. 1977. Occurrence of methyl mercury in pike and Baltic herring from the Turku archipelago. Environ. Pollution 14:227-235.

Content of methylmercury in pike, *Esox lucius*, and Baltic herring, *Clupea harengus*, from seven areas of the Turku archipelago along the SW coast of Finland was studied. Pike muscle contained an average of 0.27 mg Hg/kg wet wt. However, concentrations of methylmercury varied considerably, from 0.06 to 1.3 mg/kg, between individuals from the same fish population depending on weight (and age) of fish. Methylmercury in standardized weight (1 kg) pikes ranged between 0.19 and 0.25 mg/kg in all areas of the archipelago except near the city of Turku, where slight contamination up to 0.39 mg/kg was noticed. The level of tissue methylmercury decreased in the following order: muscle $>$liver $\geq$kidney $\gg$gonads. Liver contained from 0.03 to 2.1 mg Hg/kg wet wt from various sites, kidney 0.03 to 2.7 mg/kg, and gonads from 0.005 to 0.56 mg/kg. Baltic herring muscle contained an average of 0.09 mg Hg/kg wet wt; one-third that in pike muscle.

2795. McBride, B.C. and T.L. Edwards. 1977. Role of the methanogenic bacteria in the alkylation of arsenic and mercury. *In*: Drucker, H. and R.E. Wildung (eds.). Biological implications of metals in the environment. ERDA Symp. Ser. 42:1-19. Avail. as CONF-750929 from Nat. Tech. Inf. Serv., U.S. Dept. Comm., Springfield, VA. 22161.

Methanogenic bacteria reduce and alkylate arsenate and a number of arsenic derivatives to demethylarsine. An unidentified carbon-arsenic compound with similar properties is produced in natural anaerobic ecosystems. It appears unlikely that the methane bacteria alkylate mercury. The reaction proceeds in anaerobic ecosystems, but is probably not associated with methane biosynthesis.

2796. Mullen, T.L. and R.H. Alvarado. 1976. Osmotic and ionic regulation in amphibians. Physiological Zoology 49:11-23.

Osmomineral regulation in four species of anurans from diverse habitats was studied under aquatic conditions. *Ascaphus truei* is aquatic, *Rana pipiens* is semiaquatic, *Hyla regilla* and *Bufo boreas* are terrestrial. The rate of osmosis is faster in terrestrial forms than aquatic forms. In ul/cm^2/hr, mean values were *A. truei* = 4.0, *R. pipiens* = 4.8, *H. regilla* = 5.6, and *B. boreas* = 16.0. Higher values reflect higher skin permeability to water and a higher osmolality of body fluids.

Plasma Na^+ is closely regulated at about 2300 mg/l, which is over 100 times more concentrated than the pond water these species encounter in nature. Unidirectional fluxes of sodium were measured with Na-22 or Na-24. At a given bath concentration of Na^+, exchange rates were higher in the terrestrial species. Influx of Na^+ displays saturation kinetics with increasing bath Na^+ concentration. Over 90% of the influx is thermodynamically active. Compared with terrestrial species, aquatic species are characterized by high affinity-low capacity transport systems. Sodium efflux consists of renal and diffusive components. No exchange diffusion of Na^+ was found. Renal efflux of Na^+ was lower in aquatic species than terrestrial species. The integumentary loss of Na^+ is a function of the transepithelial electrical potential difference which is a function of bath Na^+ concentration. Body fluids become more electropositive to the bath by about 35 mV per decade increase in bath Na^+ concentration. The constant field equation accurately predicts the increase in integumentary Na^+ efflux with increasing bath Na^+ concentration. The most aquatic species, *Ascaphus*, had the lowest integumentary efflux; *Bufo*, a terrestrial form, the highest. All species maintained chloride balance in dilute baths in the face of an unfavorable electrochemical gradient. Chloride influx, measured with Cl-36, is predominantly carrier mediated, consisting of exchange diffusion and active transport in all species but *B. boreas*, in which exchange diffusion was absent. Efflux of Cl^- was lowest in *Ascaphus* and highest in *Bufo*. Renal loss was lower in aquatic species than terrestrial species. The efflux was further partitioned into diffusive and exchange diffusive components. Permeability of the skin to Cl^-, based on diffusive efflux, was lower for aquatic *Ascaphus* than for terrestrial *Bufo*. While anurans appear to possess common basic mechanisms for osmomineral regulation in freshwater, significant adaptive modifications have evolved which may affect species distribution.

2797. Nakahara, M. and F.A. Cross. 1978. Transfer of cobalt-60 from phytoplankton to the clam (*Mercenaria mercenaria*). Bull. Japan. Soc. Sci. Fish. 44:419-425.

Transfer of cobalt-60 from phytoplankton to clams was investigated to obtain additional information about the movement of cobalt-60 in the marine ecosystem. The percent retention of cobalt-60 in clams after feeding on radioactive phytoplankton varied with size of clam and with phytoplankton cell density and species of phytoplankton. At high cell densities (2×10^8 and 5×10^8 cells/l), retention of cobalt-60 by clams was reduced with increasing cell density and size of clam. More than 43% of the radioactivity introduced into the pallial cavity of clams with the diatom, Nitzschia closterium, at cell densities less than 5×10^7 cells/l was retained in clams two days after feeding.

2798. Noro, T. 1978. Effect of Mn on the growth of a marine green alga, Dunaliella tertiolecta. Japan. Jour. Phycol. 26:69-72. (In Japanese, English Summary).

Effects of manganese on growth, protein, carbohydrate, and chlorophyll content of Dunaliella during the stationary phase of growth were studied. Growth was optimal between 0.1 and 0.5 mg Mn/l. Toxic effects on growth became apparent above 10 mg/l; 16 mg Mn/l resulted in rapid death of cells. Cells grown in 0.1 mg Mn/l decreased in growth rate and cell length; carbohydrate and protein also decreased, while chlorophyll remained unaffected at this concentration. Chlorosis arose as a result of chlorophyll reduction when grown in medium lacking both iron, a hydrogenase activator, and manganese. This phenomenon was manifested exclusively under the depletion of these two elements. It is suggested that D. tertiolecta is a hydrogenase-containing alga and its chlorophyll is stable under conditions of Mn depletion.

2799. Paffenhofer, G.A. and S.C. Knowles. 1978. Laboratory experiments on feeding, growth, and fecundity of and effects of cadmium on Pseudodiaptomus. Bull. Marine Science 28:574-580.

The influence of cadmium on feeding, growth, food conversion, and reproduction of the estuarine copepod P. coronatus was studied at a Cd-concentration of 5 ug/l. Grazing, ingestion, growth rates, and gross growth efficiencies were not affected. The only detectable effect was a reduction of the daily reproductive rate to 50% of that of copepods not exposed to Cd.

2800. Parchevskii, V.P., Z.P. Burlakova, K.M. Khailov, and L.A. Lanskaya. 1977. Influence of population density of marine unicellular algae on radionuclide accumulation. Soviet Jour. Ecology 8:273-275.

Increase in population density of the algal species *Peridinium trachoideum* or *Gymnodinium kovalevskii* decreased the coefficient of accumulation (CA) for yttrium-91 and zinc-65. CA for Y-91 declined from 50,000,000 to about 10,000 as algal density rose from 0.1 to 10 mg dry wt/l; Zn-65 CA dropped from 1,000,000 to 10,000 over the same algal population range. CA of both radionuclides for any cell density was higher for *Peridinium*, which is 7X greater in surface area than *Gymnodinium*.

2801. Patrick, F.M. and M.W. Loutit. 1978. Passage of metals to freshwater fish from their food. Water Research 12:395-398.

Tubificid worms concentrated various heavy metals in mg/kg dry wt, to 32.2 (Cr), 230 (Cu), 870 (Fe), 13.7 (Mn), 160 (Pb) and 660 (Zn) after ingesting metal-enriched heterotrophic bacteria for 14 days. When tropical fish, *Hyphessobrycon serpae*, were fed these worms, fish exhibited increased tissue metal levels within 4 days. Metal content after 14 days was 5.9 to 9.1 mg Cr/kg dry wt, 146 to 199 for Cu, 144 to 181 for Fe, 18.5 to 20.0 for Mn, 36.3 for Pb, and 36.3 for Zn. Only Pb was increased in contaminated fish after 2 days. Increased levels of most metals in fish reflect metal concentrations of food if fish are exposed to food longer than 2-4 days. Older fish had lower Cu, Fe, and Zn concentrations, higher Cr, and similar Mn and Pb levels compared to young fish when fed contaminated worms.

2802. Pozzi, G. and M. Merlini. 1977. The accumulation, distribution, and loss of zinc (^{65}Zn) in the gastropod *Viviparus ater* (Cristofori and Jan). Malacologia 16:227-230.

The prosobranch gastropod, *V. ater*, is a preferred food by the freshwater fish *Lepomis gibbosus*. This snail populates the littoral zone of Lake Maggiore, a large subalpine lake of NW Italy. Reactor effluent discharges into fresh waters prompted the study of one of the radioelements, Zn-65, in this snail which is a possible source of radioactivity for the fish. Laboratory studies indicate that radiozinc is accumulated primarily in visceral mass and hepatopancreas of both sexes, that females transmit radiozinc to developing embryos, and that within 14 days snails concentrate sufficient radiozinc in soft tissues (>2,000,000 dpm/snail) to substantially add to the radioactivity of their fish predator.

2803. Ravera, O. 1977. Effects of heavy metals (cadmium, copper, chromium, and lead) on a freshwater snail: Biomphalaria glabrata Say (Gastropoda, Prosobranchia). Malacologia 16:231-236.

Effects of cadmium, copper and chromium on mortality and fecundity of adult Biomphalaria glabrata and embryo viability were investigated. Embryos were also tested for lead. Concentrations used ranged from 0.0 to 4.0 mg/l for Cd^{2+} and Cu^{2+} and from 0.0 to 1.4 mg/l for Cr^{6+}. Cadmium and copper were far more toxic than chromium. Fertility was abolished by 0.1 mg/l of cadmium and copper, and fecundity severly affected by chromium. Survival of hatchlings treated with chromium was of the same order of magnitude as controls, and sexual maturity did not show any delay. Forty-one percent of the embryos kept at concentrations of 0.1 mg/l Pb^{2+} completed their development in 51 days, that is, with a delay of 37 days. Hatchlings at 0.1 mg Pb/l died after 15 days.

2804. Saboski, E.M. 1977. Effects of mercury and tin on frustular ultrastructure of the marine diatom, Nitzschia liebethrutti. Water, Air, Soil Poll. 8:461-466.

Marine diatoms were maintained for 14 days in 1.5 ug/l of either inorganic Hg or Sn ions. Frustule abnormalities were significantly greater in diatoms grown with Hg and Sn than controls. Abnormalities common to both Hg and Sn were reduction in length and width, fused carinal dots and reduction in number of carinal dots/frustule. Curved raphes and carinal dots aligned parallel to the raphe appeared only in frustules from Sn treatment.

2805. Shultz, C.D. and D. Crear. 1976. The distribution of total and organic mercury in seven tissues of the Pacific blue marlin, Makaira nigricans. Pacific Science 30:101-107.

Tissue samples from Pacific blue marlin were collected at Kona, Hawaii, in August, 1973. Analyses of total and organic (methyl-) mercury indicated that the marlin may be biotransforming methylmercury to inorganic mercury; about 90% of mercury body burden was in the inorganic form. The difference between total and organic mercury concentrations was equal to inorganic mercury by weight. Average mercury concentrations, in mg/kg wet wt, in marlins were 4.3 total mercury and 0.4 organic mercury in muscle, 13.4 and 0.2, respectively, in liver, 7.3 and 0.2 in spleen, 0.3 and 0.1 in gill, 0.7 and 0.2 in gonad, 1.1 and 0.1 in stomach, and 0.3 and 0.1 mg/l in blood. Inorganic mercury levels were 2.3 mg/kg wet wt in muscle, 11.0 in liver, and 8.5 in spleen.

2806. Stewart, J. 1977. Relative sensitivity to lead of a naked green flagellate, Dunaliella tertiolecta. Water, Air, Soil Poll. 8:243-247.

Cells of Dunaliella spp., unicellular marine green algae, differ from most other plant cells in lacking a cell wall. Responses of D. tertiolecta grown in a synthetic seawater medium with Pb added were similar to those of other algae previously tested, disproving the idea that cell wall might "protect" cells. D. tertiolecta growth was reduced in minimum concentrations of 0.2 to 0.5 mg Pb/l after 8 days when in salinities 20, 24, and 30 o/oo. Population size was lower in 35 o/oo at each level of Pb to 2.0 mg/l, at which concentration growth regardless of salinity was greatly reduced compared to controls.

2807. Stoneburner, D.L. 1978. Heavy metals in tissues of stranded short-finned pilot whales. Science Total Environment 9:293-297.

Tissues from 4 short-finned pilot whales, Globicephala macrorhyncha, stranded at Cumberland Island National Seashore were analyzed for total cadmium, mercury and selenium. Cadmium reached a maximum mean wet wt concentration of 31.4 mg/kg in kidney. Maximum mean concentrations of mercury, 230.9 mg/kg, and selenium, 44.2 mg/kg, were found in liver. The lowest mean concentration of each metal was in blubber, at 0.2 to 2.4 mg Hg/kg, 0.8 to 1.4 mg Se/kg, and 0.3 to 0.8 mg Cd/kg. Postmortem examination showed that the whales had no food in their stomachs. The whales may have been utilizing metabolic reserves, contaminated with residual concentrations of heavy metals, prior to beaching. This utilization of reserves probably resulted in the high concentrations of Cd, Hg, and Se in liver and kidney. Since metal concentrations were 3-4X greater in stranded whales, then in apparently healthy whales of the same species, author suggests that heavy metal toxicosis may have been a factor contributing to this stranding.

2808. Thomas, W.H., D.L.R. Seibert, and M. Takahashi. 1977. Controlled ecosystem pollution experiment: effect of mercury on enclosed water columns. III. phytoplankton population dynamics and production. Marine Science Commun. 3:331-354.

Effects of inorganic mercury on natural assemblages of marine phytoplankton were studied in large plastic cylinders (CEEs) which were moored in Saanich Inlet, British Columbia, Canada, and contained associated zooplankton assemblages. Following addition of 1.0 and 5.0 ug Hg/l to two CEEs, there was an initial inhibition of productivity and phytoplankton crops as compared to controls. Bottle bioassays suggested that these levels of mercury would be inhibitory in CEEs, but that adaptation and recovery of the crops would occur. After about 21 days of mercury treatment, microflagellate crops increased in 1.0 ug Hg/l; phytoplankton that increased in 5.0 ug Hg/l were dinoflagellates and centric diatoms. These were much less abundant in controls in which a silicoflagellate bloom developed between days 42 and 72. Percent similarity and diversity indices were different in control and treated CEEs late in the experiment. Since zooplankton crops were inhibited strongly in 5.0 ug Hg/l, differences in phytoplankton taxa and crops between this CEE and the control could be attributed to differential grazing pressure.

2809. Turner, J.C., S.R.B. Solly, J.C.M. Mol-Krijnen, and V. Shanks. 1978. Organochlorine, fluorine, and heavy-metal levels in some birds from New Zealand estuaries. New Zealand Jour. Science 21:99-102.

Five species of birds: black-backed gulls *Larus dominicanus*, red-billed gulls *Larus novaehollandiae scopulinus*, South Island pied oystercatcher *Haematopus ostralegus finschi*, pied stilt *Himantopus himantopus leucocephalus*, and pukeko *Porphyrio porphyrio melanotus*, collected from 7 estuarine areas of New Zealand in 1973 and 1974 were analyzed for organochloride residues, flourine, As, Cd, Cu, Hg, Pb, Se, and Zn. Mean metal concentrations, in mg/kg wet wt or bone-ash, ranged from 0.01 to 0.99 for As in feather, 0.01 to 2.55 for As in liver, 0.08 to 1.48 for Cd in liver, 0.05 to 7.98 for Cd in kidney, 2.78 to 11.97 for Cu in liver, 0.10 to 7.99 for Hg in feathers, 0.01 to 1.15 for Hg in liver, 0.12 to 180.9 for Pb in bone, 1.18 to 4.10 for Se in kidney, and 21.1 to 87.6 for Zn in liver. Species differences for some of the heavy metals were probably related to type of diet. In general, the survey indicated little pollution of the environment, even near the most highly industrialized areas of the country.

2810. Vannucchi, C., S. Sivieri, and M. Ceccanti. 1978. Residues of chlorinated naphthalenes, other hydrocarbons and toxic metals (Hg, Pb, Cd) in tissues of Mediterranean seagulls. Chemosphere 7:483-490.

A total of 5 seagulls, Larus ridibundus, from two sites on the Mediterranean coast of Italy were captured during winter 1975-1976. Mercury, lead and cadmium levels in various tissues on a mg/kg wet wt basis, ranged as follows: liver Hg 1.32-2.39; liver Pb 2.00-18.30; liver Cd 0.22-2.60; muscle Hg 0.95-1.81; muscle Pb 2.39-11.01; muscle Cd 0.25-1.90; kidney Hg 0.62-1.40; kidney Pb 1.52-40.00; kidney Cd 0.36-2.10; brain Hg 0.65; brain Pb 30.00; brain Cd 1.40. Authors infer that these metals are present in amounts approaching toxicological interest.

2811. Winner, R.W., T. Keeling, R. Yeger, and M.P. Farrell. 1977. Effect of food type on the acute and chronic toxicity of copper to Daphnia magna. Freshwater Biology 7:343-349.

Based on survival, brood size, and instantaneous rate of population growth, Daphnia fed algae were less sensitive to a chronic copper stress than Daphnia fed a trout-granule diet. Longevity of copepods and brood size were significantly lower than controls in 20 ug Cu/l for trout food populations. Daphnia fed algae decreased in longevity in 60 ug Cu/l; brood size was similar to or greater than controls in up to 100 ug Cu/l. Maximum allowable toxic concentrations (MATC) for chronic exposure were 40 ug Cu/l and 10 ug/l for algae and trout-pellet fed Daphnia, respectively. LC-50 (72 hrs) values were not different due to diet, ranging from 81.4 to 88.8 ug Cu/l. Application factors of MATC to LC-50 (72 hrs) value ratios were 0.47 for animals on algae food and 0.12 on trout food. Authors suggested that the mechanism of toxic action is different for acute and chronic toxicity and that, if so, the ratio between chronic and acute toxicity would not be a constant under different environmental conditions.

2812. Anderson, L.W.J. and B.M. Sweeney. 1978. Role of inorganic ions in controlling sedimentation rate of a marine centric diatom Ditylum brightwelli. Jour. Phycol. 14:204-214.

Settling rates and intracellular levels of K^+, Na^+, Cl^-, Mg^{2+} and Ca^{2+} were measured in Ditylum grown axenically in an enriched seawater medium at 20 C at 4000 lux on an 8:16 LD schedule. Cells at the end of the dark period have high Na^+ (2700 mg/kg), low K^+ (2500 mg/kg) and low Cl^- (4100 mg/kg) relative to levels at the end of the light period when K^+ (4910 mg/kg) and Cl^- (5400 mg/kg) are high and Na^+ (2320 mg/kg) is low. There is no significant change in Mg^{2+} (380 to 430 mg/kg) or Ca^{2+} (120 to 160 mg/kg) with time. The net result of ion changes during the light period is to increase cell density by about 3.4 mg/ml. This change can account for the increase in settling rate of ca. 0.3/day during the same interval. The density of cell contents, calculated from observed ion concentrations, is 15 to 18 mg/ml less than seawater medium. Ion and settling rate changes are light-dependent and do not persist in the dark or under constant light (ca. 850 lx), but cells do exhibit a free-running circadian rhythm in cell division under continuous dim illumination. The cell vacuole expands during the light period and contracts during the dark, apparently in response to net ion fluxes. D. brightwelli appears to regulate its density by active ion selectivity accompanied by trans-vacuolar water movement.

2813. Anderson, M.A., F.M.M. Morel, and R.R.L. Guillard. 1978. Growth limitation of a coastal diatom by low zinc ion activity. Nature 276:70-71.

Zinc ion activity, rather than total Zn concentration, can limit the growth rate of Thalassiosira weissflogii. Laboratory studies demonstrated that this limitation occurs at zinc ion activities which would be present in unpolluted seawater if any organic complexation of zinc were taking place.

2814. Archibald, F.S. and I.W. DeVoe. 1978. Iron in Neisseria meningitidis: minimum requirements, effects of limitation, and characteristics of uptake. Jour. Bacteriology 136:35-48.

A simple defined medium was devised that does not require iron extraction to produce iron-limited growth of N. meningitidis. The defined medium was used in batch cultures to determine the disappearance of iron from the medium and its uptake by cells. To avoid a number of problems inherent in batch culture, acontinuous culture in which iron and dissolved oxygen were varied independently was used. Most of the cellular iron was found to be nonheme and associated with the particulate fraction in sonically disrupted cells. Nonheme and catalase-heme iron were reduced by iron starvation far more than cytochromes b and c and N,N,N',N'-tetramethylphenylenediamine-oxidase. The respiration rate and efficiency also decreased under iron limitation, whereas generation times increased. The iron-starved meningococcus took up iron by an energy-independent system operating in the first minute after an iron pulse and a slower energy-dependent system inhibited by respiratory poisons and an uncoupler. The energy-dependent system showed saturation kinetics and was stimulated nearly fourfold by iron privation.

2815. Berland, B.R., D.J. Bonin, O.J. Guerin-Ancey, V.I. Kapkov, and D.P. Arlhac. 1977. Action de metaux lourds a des doses subletales sur les caracteristiques de la croissance chez la diatomee Skeletonema costatum. Marine Biology 42:17-30. (In French, English summary).

Sublethal effects of mercury (5 to 10 ug/l), cadmium (25 to 100 ug/l), and copper (51 to 200 ug/l) salts on the marine diatom S. costatum grown in batch and bacteria-free culture were studied. Division rate, maximum yield, growth, mean cell volume, particulate carbon and nitrogen, and C-14-bicarbonate uptake over a period of 7 days were used as toxic impairment criteria. Division rate was the first-affected and most sensitive parameter, but algal responses varied according to the metal. Hg produced an acute decrease in division rate, followed by a temporary recovery of growth capacity within 48 hrs after metal addition. Cadmium, on the other hand, increased division rate, followed by an obvious decrease. Copper reduced division rate slowly or quickly, depending on metal concentration. Cell synthesis capacity (culture biovolume, particulate carbon and nitrogen, carbon assimilation) was less affected than division rate, especially with Hg. The C:N cell ratio was unchanged at sublethal concentrations, even when production was reduced. The mean cell volume was slightly affected; variations were not greater than those of controls during its growth phases. Markedly teratological forms were never observed. Authors concluded that many parameters and growth kinetic aspects must be considered in evaluating the effects of sublethal concentrations of heavy metals.

2816. Betzer, S.B. 1972. Copper metabolism, copper toxicity, and a review of the function of hemocyanin in *Busycon canaliculatum* L. Ph.D. thesis, Univ. Rhode Island, Kingston, RI: 133 pp.

The marine gastropod, *Busycon canaliculatum*, was captured at all seasons of the year and dissected for analysis of copper content of individual tissues. Despite a high degree of individual variation in tissue Cu concentrations (mg/kg fresh wt), seasonal trends were evident. Generally, concentrations were low in winter and early spring, increasing 5- to 10-fold in early summer, and decreasing in autumn. The early summer increases correlated with time of emergence from the sediment and commencement of feeding. The average Cu concentration in whole soft tissues of whelks captured in summer was 76 mg/kg with digestive gland accounting for 60% of total Cu. Radioactive Cu-64 was used to trace uptake from seawater by whelks. Uptake by whole animals followed a smooth curve which slowed with time; about 2/3 of the available labeled Cu was absorbed by 48 hrs. The rate of Cu uptake was generally proportional to Cu concentration in medium. Shell accounted for about 30% of the accumulated Cu. Among soft tissues, Cu-64 appeared at 1 hr on gills, in blood, and in kidney. By 6 hrs Cu-64 appeared in gut and digestive gland, and continued to accumulate in the digestive gland, so that by 48 hrs it contained 50% of the total Cu taken up by gills and organs of the visceral mass. Transfer of absorbed Cu-64 to the digestive gland continued even when exposed whelks were removed to unlabeled water for 24 hrs. Separations carried out on blood labeled with Cu-64 indicated that absorbed Cu was nonspecifically bound to hemocyanin. Excretion rates for Cu by *Busycon* were found to average about 70 ug/24 hrs per kg tissue wt in spring and summer. Rates did not appear to be affected by Cu concentration of the medium. Under normal environmental Cu concentrations, rates of dissolved Cu uptake and Cu excretion are probably about equal. A calculation of the amount of Cu shed at spawning in the autumn (based on determinations of the Cu concentration of *Busycon* egg capsules, averaging 23 ug/capsule) showed that this could be a significant route for Cu loss. A possible increase in Cu excretion in autumn, correlating with observed increases in kidney Cu concentration, is also suggested as an explanation for the drop in Cu concentrations of other tissues at this season. Whelks were exposed to high concentrations of ionic Cu in seawater (up to 1000 ug/l), and effects were followed histologically, by determination of tissue Cu concentrations, and by tracing uptake with Cu-64. The whelk showed a high degree of resistance to ionic Cu. At lethal concentrations, Cu was accumulated at the gill and osphradium. These tissues also showed progressive histopathologic changes, including swelling of gill fimaments, amebocytic infiltration of connective tissue, and necrosis and swelling of mucosa.

2817. Bitton, G. and V. Freihofer. 1978. Influence of extracellular polysaccharides on the toxicity of copper and cadmium toward _Klebsiella_ _aerogenes_. Microbial Ecology 4:119-125.

Exposure of various bacterial strains of _Klebsiella_ to 10 mg/l of Cu^{2+} for 7 hours reduced survival by a 4 to 5 log reduction factor. Cadmium at 10 mg/l was less toxic than copper, with a 0.5 to 2.0 log reduction factor in 7 hours. In all cases, capsular strains were more resistant than non-capsulated strains. This was attributed to complexing properties of capsular polysaccharides.

2818. Brenner, F.J. and W.L. Cooper. 1978. Effect of suspended iron hydroxide on the hatchability and embryonic development of the coho salmon. Ohio Jour. Sci. 78:34-38.

Oncorhynchus _kisutch_ eggs were fertilized and fry incubated at 10 C in the presence and absence of suspended iron. Suspended ferric hydroxide at 3.0 mg/l had no apparent effect on hatchability, embryonic development, or survival and maturation of newly hatched coho salmon. Eggs exposed to iron hatched within 51 days, with 96% survival, _vs_ 53 days with 99% survival for controls. Total mortality among alevins after 90 days was 6.1% in 3.0 mg Fe/l, and 4.0% without Fe.

2819. Carlsson, S. and K. Liden. 1978. ^{137}Cs and potassium in fish and littoral plants from a humus-rich oligotrophic lake 1961-1976. Oikos 30:126-132.

Results of a 15-year study on concentrations of Cs-137 from fallout in some species of fish and littoral plants in a humus-rich oligotrophic lake are presented. High concentrations of Cs-137 were detected in the different species studied. This is in agreement with the general observation that organisms in oligotrophic lakes have higher concentrations of the radionuclide than lakes of other limnological types. The maximum values of Cs-137 were found in 1964 or 1965, depending on the species studied. Concentrations have decreased 20 to 30% of the maximum value by 1975. A seasonal variation in concentration of Cs-137 in fish (pike, *Esox lucius*; perch, *Perca fluviatilis*; roach, *Rutilus rutilus*; rudd, *Scardinius erythrophtalmus*) was noted with the highest value occurring during the first quarter of the year. This is explained by the strong temperature dependence of excretion of Cs-137. No seasonal variation in the concentration of potassium is seen in fish. The plant species *Equisetum fluviatile* and *Carex rostrata* have seasonal variations in concentration of both Cs-137 and potassium, with highest values at the beginning of the growing season. In various species of fish studied a relationship was derived between the concentration of Cs-137 and the size of the fish. The results are discussed in terms of changes in feeding habits and changes in excretion of the radionuclide. The concentration of Cs-137 in fish was observed to follow a trophic level increase. The concentration is increased by a factor of two between each level.

2820. Carrano, C.J. and K.N. Raymond. 1978. Coordination chemistry of microbial iron transport compounds: rhodotorulic acid and iron uptake in *Rhodotorula pilimanae*. Jour. Bacteriology 136:69-74.

The mechanism by which iron uptake is facilitated by the siderophore rhodotorulic acid (RA) in the yeast *Rhodotorula pilimanae* was investigated with radioactively labeled Fe and RA and chromic-substituted RA complexes. The evidence supports a model in which RA mediates iron transport to the cell but does not actually transport iron into the cell. It is proposed that RA exchanges the ferric ion at the cell surface with a membrane-bound chelating agent that completes the active transport of iron into the cell. Uptake of Fe-55 ferric rhodotorulate was much more rapid than uptake of RA itself. Two exchange-inert chromic complexes of RA showed no uptake.

2821. Carter, J.G.T. and W.L. Nicholas. 1978. Uptake of zinc by the aquatic larvae of *Simulium ornatipes* (Diptera: Nematocera). Austral. Jour. Marine Freshwater Res. 29:299-309.

Uptake and loss of zinc by aquatic larvae of blackfly, *S. ornatipes*, was investigated using radioactive Zn-65. Larvae absorbed zinc from solution, up to 11 mg Zn/kg wet wt in 0.1 mg Zn/l after 24 hrs. A substantial proportion of Zn remained in the body when larvae were transferred to zinc-free water. Insects contained 2.0 mg/kg after 32 hrs in clean water. Uptake was assisted by metabolism, but an increase of calcium ion concentration, although reducing toxicity, had no effect on uptake, exchange, or loss of zinc. In the cuticle and high-molecular-weight fractions of larvae, two pools were identified; one in which zinc is weakly held and exchanges rapidly with zinc in solution; and one where zinc is held and exchanges slowly. Exposure time, temperature, and external concentration influenced the quantity of zinc entering these pools. High molecular fractions contained 60% of Zn-65 in whole larvae after 60 hr exposure. Zinc was probably bound by phenolic groups in the cuticle fraction, and by phosphonic acids in the high-molecular-weight fraction. Sulfhydryl groups did not bind a major portion of the zinc.

2822. Chalker, B.E. 1976. Calcium transport during skeletogenesis in hermatypic corals. Comp. Biochem. Physiol. 54A:455-459.

Light-enhanced calcification in the hermatypic corals _Acropora cervicornis_ and _A. formosa_ results from the active transport of calcium ions. Dark calcification results from enzyme mediated isotopic exchange. Strontium is a competitive inhibitor of both light-enhanced and dark calcification. The data refutes the diffusional model for calcium movement in hermatypic corals.

2823. Decleir, W., A. Vlaeminck, P. Geladi and R. Van Grieken. 1978. Determination of protein-bound copper and zinc in some organs of the cuttlefish _Sepia officinalis_ L. Comp. Biochem. Physiol. 60B:347-350.

The copper, zinc and iron content of blood and water soluble extracts from several organs of _Sepia officinalis_ were determined by atomic absorption spectrometry. The relatively high concentration of copper (up to 70 mg/kg dry wt) and zinc (up to 124 mg/kg dry wt) in the branchial gland points to its probable role in trace element metabolism. After gel filtration a low molecular weight copper and zinc containing fraction can be isolated from the gland. A possible role of this fraction in hemocyanin biosynthesis is postulated.

2824. Findley, A.M. and W.B. Stickle. 1978. Effects of salinity fluctuation on the hemolymph composition of the blue crab *Callinectes sapidus*. Marine Biology 46:9-15.

Crab hemolymph was hyperosmotic during 20-10-20 o/oo S and 30-10-30 o/oo S diurnal cycles. The hemolymph became isomotic at 26 o/oo S and hyposmotic at 28 o/oo S in the 10-30-10 o/oo S diurnal cycle. Hemolymph Na$^+$ was hyperionic to seawater throughout all cycles. Hemolymph Cl$^-$ was hyperionic below 24 o/oo S and either isionic or hypoionic from 24 to 30 o/oo S. Hemolymph K$^+$ concentrations were hyperionic below 26 o/oo S and either isionic or hypoionic from 26 to 30 o/oo S. Hemolymph Mg^{2+} values were hypoionic over the experimental salinity range of 10 to 30 o/oo. Hemolymph ninhydrin-positive substances levels were directly related to ambient salinity.

2825. Foster, R.B. and J.M. Bates. 1978. Use of freshwater mussels to monitor point source industrial discharges. Environ. Science Technol. 12:958-962.

In-stream monitoring techniques were used to evaluate effects of copper electroplating wastes on mussel fauna of the Muskingum River, Ohio. Laboratory effluent bioaccumulation tests were conducted with freshwater mussels and copper, the major effluent constituent. Mussels were also exposed in cages at various distances from the electroplating plant outfall and analyzed for copper content after 14, 30 and 45 days. Indigenous mussels were also analyzed for copper. Copper accumulation in the species tested, *Quadrula quadrula*, was inversely related to body weight. Mortalities during effluent exposures occurred after 11 days and were associated with body burdens approaching 20 mg Cu/kg wet wt. Analysis of caged mussel specimens when correlated with Muskingum River population surveys and natural background content of copper in freshwater mussels demonstrated an adverse impact of the electroplating plant within 21 km of the outfall. Mussels caged 0.1 km from the outfall accumulated 20.64 mg/kg Cu in 14 days, 10X the normal body burden of mussels at control stations upstream. The copper content of caged mussels at stations located 5 to 53 km downstream declined as the distance from the outfall increased. The impact of the electroplating plant effluent on the Muskingum River mussel fauna was significant, causing population mortalities of 60% within 5 km and 39% within 21 km.

2826. Fukai, R., B. Oregioni, and D. Vas. 1978. Interlaboratory comparability of measurements of trace elements in marine organisms: results of intercalibration exercise on oyster homogenate. Oceanologica Acta 1:391-396.

An intercalibration exercise of trace element measurements was organized by using an oyster (Ostrea edulis) homogenate sample to examine the state of the art of measurement performance, with the aim of improving the comparability of results; 87 laboratories, on a world-wide basis, participated in this operation. The results of analyses on 12 selected trace elements (Cr, Mn, Fe, Co, Cu, Zn, As, Se, Ag, Cd, Hg, and Pb) were treated statistically to deduce the "consensus values" of these elements in the sample. The results of selected laboratories were treated similarly to estimate "probable concentrations". The "probable concentrations" agree with "consensus values" for most elements. On the basis of "probable concentrations", ranges for acceptable values were estimated for each element. More than 80% of the results reported were within estimated acceptable ranges for Mn and Cu; more than 70% for Cr, Zn, Se, Cd, and Hg; more than 60% for Fe, Co and Ag; while 59% were acceptable for Pb and only 43% for As. General observations made on analytical methods used, presentation of data, and other aspects are also given.

2827. Fyhn, H.J. 1976. Holeuryhalinity and its mechanisms in a cirriped crustacean, Balanus improvisus. Comp. Biochem. Physiol. 53A:19-30.

Euryhalinity of barnacles depends partly on hyperosmotic regulation of hemolymph and partly on cell volume regulation. B. improvisus osmoconform in water above 500 mOsm and osmoregulate in more dilute seawaters, showing strict homoiosmoticity below 100 mOsm. Hemolymph and maxillary gland fluid are isomotic and have equal chloride concentrations. Seventeen free amino acids are found in thorax muscle tissue in amounts varying with hemolymph osmolality. Proline reaches unique values of 0.7 M at hypersaline seawater. The relative water content of muscle tissue varies little with changes in hemolymph osmolality pointing to a regulation of cell volume. Adjustments of intracellular amino acids, especially proline, assist in this regulation. The intermoult cycle does not significantly influence measured parameters.

2828. Gertz, S.M. and I.H. Suffet. 1977. The biological fate of radionuclides in aquatic environments. In: Suffet, I.H. (ed.). Fate of pollutants in the air and water environments. Advan. Environ. Sci. Technol. 8:223-238.

Three levels were presented to describe algal uptake of radioactivity. Level I described radionuclide uptake in terms of concentration factors. This level is basic to the study of radionuclide uptake but it is not complete. Level II considered algal radionuclide uptake in terms of concentration factors and those environmental stresses which may affect an organism's biomagnification potential. This level, while a higher level of understanding than Level I, is still not complete, for while the phenomenon is better quantified, the reason for the phenomenon is still not known. Level III, the highest level, considers the biological mechanisms that permit and cause an organism to accumulate radioactivity. Algal accumulation of cesium and strontium and modifications by magnesium, calcium, sodium, potassium, and temperature are presented as examples.

2829. Goldman, M., R.D. Dillon, and R.M. Wilson. 1977. Thyroid function in Pekin ducklings as a consequence of erosion of ingested lead shot. Toxicol. Appl. Pharmacol. 40:241-246.

Young ducklings received three or six lead shot which were dropped down the throat of each bird. Lead shot recovered from gizzards at necropsy were smaller and more irregular in shape than when introduced. Although erosion rate was similar in both groups receiving lead shot, total amount of lead eroded was greater in birds receiving the greater number of shot. After 16 days, the 3 shot group accumulated 360 mg Pb and the 6 shot group accumulated 670 mg Pb from pellets. Body weight gain was significantly lower in waterfowl receiving 6 shot. Birds fed 6 shot showed major signs of lead poisoning such as green diarrhea, weakness, and lethargy. Thyroid weight and 24 hr thyroidal uptake of I-125 were increased while serum protein-bound I-125 was reduced in contaminated birds. Chromatographic analyses of thyroid hydrolysates revealed a depression in iodothyronine labeling.

2830. Grimanis, A.P., D. Zafiropoulos, and M. Vassilaki-Grimani. 1978. Trace elements in the flesh and liver of two fish species from polluted and unpolluted areas of the Aegean Sea. Environ. Sci. Technol. 12:723-726.

Concentrations of As, Cd, Co, Cu, Fe, Hg, Rb, Sb, Se, and Zn were determined in flesh and liver of two edible fishes, *Sargus annularis* and *Gobius niger*, caught from polluted and unpolluted areas of the Aegean Sea. Increased levels of arsenic were found in flesh of *Sargus* from polluted areas at 6.4 to 9.1 mg/kg dry wt (*vs*. 2.4 for unpolluted area). Arsenic levels were also increased in flesh and liver, 18 to 140 and 8.4 to 17 mg/kg dry wt, respectively, of *Gobius* from the Athens sewage outfall area. Elevated concentrations to 1.9 mg/kg mercury were found in flesh of *Sargus* and up to 0.33 in flesh and 0.72 in liver of *Gobius* from a sea area close to Mytelene Harbor in the island of Lesvos. Elevated levels of arsenic and mercury found in these two species of edible fish from polluted areas were not high enough to render them dangerous for human consumption. No significant differences were found for all the other elements measured. Maximum metal concentrations, in mg/kg dry wt, in flesh of *Sargus* were <0.3 for Cd, 1.7 for Cu, 0.04 for Sb, 1.4 for Se, 71 for Zn, 40 for Fe, 0.04 for Co, and 2.9 for Rb; in liver of *Sargus* maximum levels were <0.3, 35, <0.02, 6.6, 111, 530, 0.6, and 2.8, respectively; in flesh of *Gobius*, <0.3, 1.3, <0.02, 1.4, 58, 25, 0.02, and 2.6; and in liver of *Gobius*, 0.91, 8.1, 0.03, 2.6, 22, 240, 0.05, and 0.78, respectively.

2831. Guary, J.C. and A. Fraizer. 1977. Etude comparee des teneurs en plutonium chez divers mollusques de quelques sites littoraux fransais. Marine Biology 41:263-267. (In French, English summary).

Plutonium contents of 4 species of gastropods: *Crepidula fornicata*, *Patella vulgata*, *Littorina littoralis*, *Nucella lapillus*; and 5 species of bivalve molluscs: *Venerupis decussata*, *Ensis ensis*, *Mytilus edulis*, *Ostrea edulis*, *Crassostrea gigas*, from several sites along the French coast were measured to determine distributional patterns of plutonium levels. The influence of the La Hague nuclear fuel reprocessing plant was apparent in the immediate proximity of the waste-disposal outfall (Ecalgrain Bay), and to a lesser degree in an oyster farming center situated about 50 km east of the Bay of Ecalgrain (St. Vaast-la-Hougue). Plutonium concentrations in molluscs from the remaining sites were quite comparable to levels that have been measured in similar species subject only to plutonium from atmospheric fallout. All molluscs, except those from Ecalgrain Bay, displayed higher levels of plutonium in the shell than soft parts, a finding in agreement with similar studies. Individuals sampled from the vicinity of the outfall consistently displayed shell:soft parts plutonium ratios of less than 1.0. This difference may reflect different physico-chemical forms of the isotope at the various sampling stations. With the exception of *Crepdidula* shell, the tissues of filter-feeding molluscs do not appear to concentrate plutonium above the level found in other types of molluscs.

2832. Guary, J.-C., M. Masson, and A. Fraizier. 1976. Etude preliminaire, *in situ*, de la distribution du plutonium dans differents tissues et organes de *Cancer pagurus* (crustacea:decapoda) et de *Pleuronectes platessa* (pisces:pleuronectidae). *Marine Biology* 36:13-17 (In French, English summary).

Plutonium distribution was determined in tissues and organs of the crab, *Cancer pagurus*, and the plaice (flatfish), *Pleuronectes platessa*, collected inshore near the La Hague fuel reprocessing plant, France. There is an observed transfer of plutonium from seawater to gills (102 pCi/kg wet wt) and exoskeleton (2.2 pCi/kg wet wt) of the crab, these organs representing a large surface adsorption. In plaice, only gut strongly accumulated plutonium (64 pCi/kg wet wt), indicating contamination by feeding. The edible parts of these two marine species, particularly the flesh, do not constitute, for man, an important source of contamination by environmental plutonium.

2833. Hattula, M.L., J. Sarkka, J. Janatuinen, J. Paasivirta, and A. Roos. 1978. Total mercury and methyl mercury contents in fish from Lake Paijanne. Environ. Pollution 17:19-29.

Total mercury and methylmercury in freshwater fishes from Lake Paijanne, Finland, were determined. This is the second largest lake in Finland and has been heavily contaminated by mercury from pulp and paper industries, chlor-alkali plants, and other sources. Twelve species of fish were analysed during a 4-year period. The average mercury concentration for all fish was 0.65 mg/kg on a fresh wt basis, of which 98.7% was in a methylated form. The concentration of mercury in fish differed in different parts of the lake and also depended on the weight of the fish. Maximum values recorded for total mercury, in mg/kg wet wt (presumably fish axial musculature), were 2.94 for smelt, 3.96 for pike, 1.13 for roach, 4.34 for burbot, 1.57 for ruffe, 2.98 for pikeperch, 4.68 for perch, and <1.0 for whitefish, vendace, bream, and carp.

2834. Hoyaux, J., R. Gilles, and C. Jeuniaux. 1976. Osmoregulation in molluscs of the intertidal zone. Comp. Biochem. Physiol. 53A:361-365.

Gastropods, *Littorina littorea*, *Purpura lapillus*, *Patella vulgata*, and bivalves, *Mytilus edulis*, *Scrobicularia plana*, *Glycymeris glycymeris*, of the littoral area behave as poikilosmotic animals when acclimated gradually to diluted media. However, when transferred directly to the more diluted medium, these molluscs react by shell-closing, leading to a transitory hyperosmotic state of the blood and perivisceral fluids. In the euryhaline molluscs studied, osmoregulation is achieved by isomotic regulation of the intracellular medium. Free amino acids and taurine play a significant part as osmotic effectors in this regulation, except in the case of the chiton *Acanthochitona discrepans*. The part played by the amino-acid pool as well as the nature of the prominent acids at work in the regulation of the intra-cellular osmolarity varies from species to species with no single general pattern emerging.

2835. Huner, J.V., J.G. Kowalczuk, and J.W. Avault, Jr. 1976. Calcium and magnesium levels in the intermolt (C_4) carapaces of three species of freshwater crawfish (Cambaridae:Decapoda). Comp. Biochem. Physiol. 55A:183-185.

Mean calcium (25.1, 24.9 and 25.4%) and magnesium (0.408, 0.428 and 0.421%) concentrations in the carapaces of intermolt (C_4) *Orconectes virilis*, *Procambarus alleni*, and *Procambarus clarkii* did not differ significantly. Mature (sexually active) crawfish apparently have much thicker cuticles than rapidly growing mature (sexually inactive) and juvenile crawfish of the same size.

2836. Iordachescu, D., I.F. Dumitru and S. Niculescu. 1978. Activation by copper ions of mytilidases - acid proteolytic enzymes obtained from *Mytilus galloprovincialis*. Comp. Biochem. Physiol. 61B:119-122.

Cu^{2+} ions, at 3810 ug/l as $CuCl_2$, strongly activated acid proteases purified from the hepatopancreas of mussels *Mytilus galloprovincialis*. Tyrosine liberation peaked at 90 nmoles/ml/min at 50 C with copper, compared to 50 nmoles for controls. In the presence of the effector, the first optimal pH was displaced from 1.5 to 1.85. Inhibition occurred at high hemoglobin concentrations. Copper ions did not protect acid proteases from the denaturing effect of temperature, while hemoglobin had a heat-protector effect.

2837. Kwasnik, G.M., Jr., R.J. Vetter, and G.J. Atchison. 1978. The uptake of manganese-54 by green algae (Protococcoidal chlorella), Daphnia magna, and fathead minnows (Pimephales promelas). Hydrobiologia 59:181-185.

Concentration factors (CF) of Mn-54 for freshwater algae, daphnids, and minnows were determined following direct exposure to the isotope in solution. The maximum accumulation (CF=911) in P. chlorella was reached at 48 hrs of exposure; the maximum uptake (CF=65) in Daphnia was reached at 8 hrs of exposure; and the maximum accumulation (CF=22.6) in fathead minnows was at 128 hrs of exposure. The data indicate that Mn-54 accumulation decreases with ascent within a theoretical aquatic food chain when water is the only source of contamination.

2838. Larochelle, J. and A. Gagnon. 1976. Osmoregulation in Acanthamoeba castellanii - II. variations of the concentrations of some intracellular ions. Comp. Biochem. Physiol. 54A:275-279.

The free-living soil amoeba A. castellanii undergoes changes in water content when incubated in media of different osmotic pressures. In this study the intracellular concentrations of K, Na, Mg, Ca, and Cl were determined following incubation in media having different salt contents but the same osmotic pressures, namely 40, 200, and 500 mOsm. The intracellular K concentration changes as a function of the osmotic pressure of the medium and is independent of its salt content. The amoeba Cl concentration is affected by both the osmotic pressure and the composition of the media. The intracellular Na concentration depends upon the levels of the Na and Ca in the external media.

2839. Manly, R. and W.O. George. 1977. The occurrence of some heavy metals in populations of the freshwater mussel Anodonta anatina (L.) from the River Thames. Environ. Pollution 14:139-154.

Concentrations of Zn, Ni, Pb, Cd, Cu and Hg in Anodonta anatina from three urban and four rural localities along the River Thames were determined. The apparent influence of urban sewage outfalls was reflected by the relatively higher concentrations of Zn, Ni, Pb and Cd in mussels from the former areas, while Cu and Hg, metals which have more diffuse inputs, showed no such relationship. The maximum concentrations recorded in this study, in mg metal/kg dry wt soft parts, were Zn 3226, Ni 46, Pb 79, Cd 21, Cu 222 and Hg 12 exceeded those previously observed in Anodonta spp. and many marine lamellibranchs from the British Isles. Considerable differences were observed in the concentrations of all metals in mussels from the same locality, particularly among immature individuals. Except for Ni, these differences were variously correlated with the dry body weight of mussels in the more highly contaminated populations. None of the metals was evenly distributed throughout the tissues of mussels. Generally, the mantle, ctenidia and kidneys contained the highest concentrations. An evaluation is made of the potential of the species as an indicator organism.

2840. Milne, R.S. and D.J. Randall. 1976. Regulation of arterial pH during fresh water to sea water transfer in the rainbow trout Salmo gairdneri. Comp. Biochem. Physiol. 53A:157-160.

Plasma Cl^-, HCO_3^-, arterial blood pCO_2, and pH and CO_2 excretion were not affected by transfer of trout from freshwater to seawater. Carbonic anhydrase activity in trout gill epithelium is low compared with that for goldfish and seawater coho salmon, but similar to that in freshwater coho salmon. The results are discussed in relation to various models for ion transport across the fish gill. It is concluded that a Cl^-/HCO_3^- exchange mechanism is reduced in gill epithelium of trout compared with goldfish.

2841. Morel, N.M.L., J.G. Rueter, and F.M.M. Morel. 1978. Copper toxicity to Skeletonema costatum (Bacillariophyceae). Jour. Phycology 14:43-48.

This marine alga is relatively insensitive to cupric ion activity under controlled laboratory conditions. Cultures inoculated from stationary phase stocks exhibit a prolongation of the lag phase with increasing copper concentrations near and above the point of precipitation of the copper. The toxicity of copper is a function of the silicic acid concentration in the medium. This effect is observed in a range of $Si(OH)_4$ concentrations

(10^{-5} M to 10^{-4} M) above known values for the saturation of silicon uptake kinetics, thus suggesting an influence of copper on silicate metabolism.

2842. Nordlie, F.G. 1976. Influence of environmental temperature on plasma ionic and osmotic concentrations in *Mugil cephalus* Lin. Comp. Biochem. Physiol. 55A:379-381.

Plasma Na^+ in mullet ranged from a concentration of 159 meq/l in fish acclimated to 10 C to 178 meq/l in fish at 30 C; plasma Cl^- ranged from 139 meq/l at 10 C to 158 meq/l at 30 C; plasma osmotic concentration ranged from 323 mOsm/kg to 378 mOsm/kg for the same acclimation temperature range. Plasma K^+ remained roughly constant. These patterns of response in inorganic ions and total osmotic concentrations to environmental temperature are opposite to that expected in fishes acclimated to seawater and infers an additional metabolic expenditure for regulation at lowered temperatures.

2843. Penrose, W.R., H.B.S. Conacher, R. Black, J.C. Meranger, W. Miles, H.M. Cunningham and W.R. Squires. 1977. Implications of inorganic/organic interconversion on fluxes of arsenic in marine food webs. Environ. Health Perspec. 19:53-59.

An organic form of arsenic is commonly encountered in marine organisms. In greysole *Glyptocephalus cynoglossus* and shrimp, organoarsenic accounted for all arsenic found in muscle tissue. It has been isolated from flounder tissue by two independent procedures and found to be hydrophilic, cationic, and not decomposed to inorganic arsenic by hot nitric and sulfuric acids. Nuclear magnetic resonance spectroscopy indicated all nonexchangeable protons to be equivalent, with behavior more similar to N-methyl protons than As-methyl protons. High-resolution mass spectroscopy from a heated probe yielded a spectrum corresponding to tetramethylarsonium ($AsMe_4^+$). The authentic ion, however, had thin-layer chromatography and ion-exchange behavior different from that of the natural product. Infrared spectrometry likewise produced conflicting or uninterpretable data. Decomposition of the compound for analytical purposes was accomplished by dry ashing under oxidizing conditions. Sea urchins, *Strongylocentrotus droebachiensis*, like trout, converted arsenic to an organic form, but to a more limited degree. Arsenic found naturally in sea urchins and in a species of macroalga Fucus vesiculosus was also organic. In individual containers, sea urchins were fed on the alga for 7 weeks. During this time they consumed 0.203 mg total As and excreted only 0.036 mg as feces. Measurement of inorganic As in the seawater did not account for the discrepancy, but measurements of total As did (0.202 mg). Sea urchins, like humans, appear to be able to rapidly excrete these organic forms of arsenic.

2844. Pentreath, R.J. 1977. The accumulation of ^{110m}Ag by the plaice, Pleuronectes platessa L. and the thornback ray, Raja clavata L. Jour. Exp. Marine Biol. Ecol. 29:315-325.

Accumulation of stable Ag and Ag-110m from both food and water by a marine fish (plaice) and elasmobranch (thornback ray) has shown that metabolism of silver by these two species is markedly different. Silver levels, in mg/kg wet wt, in plaice exposed to 0.04 mg Ag/l for 2 months ranged from 0.01 in muscle to about 0.05 in liver and heart, with concentration factors (CF) up to 1200. In contrast, the elasmobranch had tissue concentrations ranging from 0.008 mg Ag/kg wet wt in blood cells to 0.56 in kidney and 1.47 in liver; CF reached 14,000 and 37,000 in kidney and liver. Direct accumulation of Ag-110m from seawater was low for both species, but higher for rays. CF values rose to about 15 for whole body accumulation in rays over 63 days, and to 2 for plaice. Ag-110m concentrations in tissues of plaice over blood plasma ranged from 0.3 in blood cells to 1.6 in gill filaments, 1.8 in liver and 2.3 in brain. After depuration for 43 days, maximum radionuclide levels over plasma were 3.6, 3.8, and 4.0 in spleen, liver, and bladder, and 14.4 in brain. Ag-110m accumulations over plasma after 63 days in rays were up to 117 in stomach, 138 in gill filaments, and 1900 in liver; after 43 days loss, CF over plasma were 89 to 285, 52 to 118, and 4200 to 4600 in respective tissues. Retention of Ag-110m from labelled worms, Nereis, by plaice was poor: only 4% after 3 days, with a very short biological half-time. In contrast, rays retained 48% of the radionuclide from labelled food, with a long biological half-time and with very high concentrations in liver. Livers from rays caught near a nuclear fuel reprocessing plant contained Ag-110m, but this isotope could not be detected in plaice liver.

2845. Pesch, C.E. and D. Morgan. 1978. Influence of sediment in copper toxicity tests with the polychaete Neanthes arenaceodentata. Water Research 12:747-751.

Adult male marine worms were exposed to measured concentrations of 0.04, 0.06, 0.10, 0.16 and 0.26 mg Cu/l in a continuous-flow bioassay system, with and without a clean sand. The 28-day LC-50 was lower (0.044 mg Cu/l) for polychaetes exposed without sand than those with sand (0.100 mg Cu/l). Neanthes surviving exposure for 28 days at various Cu concentrations in a sand substrate consistently contained lower whole body Cu residues than Neanthes in a sand-free substrate.

2846. Planas, D. and F.P. Healey. 1978. Effects of arsenate on growth and phosphorus metabolism of phytoplankton. Jour. Phycology 14:337-341.

The response to arsenate in growth and phosphate uptake by five species of algae in culture varied considerably. The growth rates of Melosira granulata and Ochromonas vallesiaca were depressed by 1.0 uM arsenate. Chlamydomonas reinhardtii required 10 uM for the same degree of depression, while the growth rates of Cryptomonas erosa and Anabaena variabilis were unaffected up to 100 uM. However, following depletion of phosphate, cultures of the latter two algae began to die at the higher concentrations of arsenate tested. Growth of C. reinhardtii in the presence of 35 uM arsenate resulted in characteristics of P deficiency. Comparison of rates of photosynthesis, respiration, and phosphate uptake between cultures of C. reinhardtii grown in the presence and absence of arsenate showed little evidence after 16 doublings that it had adapted to arsenate.

2847. Prusch, R.D., D.J. Benos, and M. Ritter. 1976. Osmoregulatory control mechanisms in freshwater coelenterates. Comp. Biochem. Physiol. 53A:161-164.

Contraction rate of the body column of Hydra littoralis is affected by Na^+, CN and ouabain added to the external medium. The electrical potential across the hydra body wall is decreased by a decrease in the external Na^+, and by decreased temperature. Enteron Na^+ and K^+ levels are influenced by a variety of experimental conditions. Osmoregulation in freshwater coelenterates is influenced by both external Na^+ and total external osmolality.

2848. Reiniger, P. 1977. Concentration of cadmium in aquatic plants and algal mass in flooded rice culture. Environ. Pollution 14:297-301.

Concentrations of Cd in aquatic plants Elatine hexandra, Althenia filiformis and Monita rivularis on a flooded rice soil contaminated with up to 24 mg Cd/kg largely exceeded cadmium concentrations found in leaves and roots of rice plants. The accumulation of Cd by the algal mass was considerable, with a concentration factor of around 10,000 relative to the surface water. The quantity of Cd accumulated by the algal mass in a rice field may be comparable to that in leaves of rice plants. Mean Cd concentrations, in mg/kg wet wt, for rice leaves (roots) grown in soil containing 2, 8, or 24 mg/kg of added Cd were 6(0.2), 20(0.3), and 50(0.5), respectively.

2849. Reish, D.J., C.E. Pesch, J.H. Gentile, G. Bellan, and D. Bellan-Santini. 1978. Interlaboratory calibration experiments using the polychaetous annelid Capitella capitata. Marine Environ. Res. 1:109-118.

An interlaboratory calibration experiment was conducted at installations in California, Rhode Island, and France in order to test two sources of variation associated with toxicity bioassay experiments: variation due to the experimenter, and variations due to the natural seawater. Twenty-eight day static (with frequent media renewal) bioassays with polychaetes Capitella capitata and cadmium salts were conducted with synthetic and natural seawaters. Test results varied between the 3 laboratories, with LC-50 (28 day) values extending from 0.40 to 1.50 mg Cd/l. However, variations might be attributable to extreme temperatures experienced by worms during some air transshipments.

2850. Robertson, D.R. 1976. Diurnal and lunar periodicity of intestinal calcium transport and plasma calcium in the frog, Rana pipiens. Comp. Biochem. Physiol. 54A:225-231.

Calcium transport in frog duodenum displayed wide amplitude diurnal changes with maximum transport at night, while diurnal changes were of low magnitude in the jejunum and ileum. Diurnal patterns at four major lunar phases throughout the synodical lunar month show peaks of activity that correspond to times of high and low lunar transit. Maximal plasma calcium levels are coincident with maximal periods of duodenal calcium transport.

2851. Rossi, L.C., G.F. Clemente, and G. Santaroni. 1976. Mercury and selenium distribution in a defined area and in its population. Arch. Environ. Health 31:160-165.

In the Amiata Mountain area of Tuscany, Italy, concentrations of mercury and selenium were examined in the environment, in the food chain, and in human blood, urine, and hair. This area has large mineral deposits and concentrations of iron, copper, silver, antimony, and particularly mercury. Subjects consisted of a group with high occupational exposure to mercury vapor, a group randomly exposed to mercury dust, and a group nonoccupationally exposed to mercury. Maximum mean Hg concentrations were found in humans with high exposure: 59 ug Hg/l in whole blood, 93 ug/l in serum, 44 ug/l in blood cells, 251 ug/l in urine, and 25 mg/kg in hair. Selenium content in these subjects was 133 ug Se/l in whole blood, 60 in serum, 19 in blood cells, 8.2 in urine, and 7.6 mg/kg in hair. Autopsies of 3 miners showed maximum mercury, at 240 to 3000 ug/kg wet wt, and selenium, at 267 to 680 ug/kg, in kidney. Edible freshwater fishes *Barbus barbus plebejus*, *Leuciscus cephalus cabeda*, *Rutilus rubilio*, and *Salmo trutta fario* contained mean values of 180 to 524 ug Hg/kg wet wt and 192 to 284 ug Se/kg, the highest concentrations in foodstuffs examined. Aquatic plants and mosses contained 400 and 4000 ug Hg/kg dry wt, respectively, and 100 and 750 ug Se/kg dry wt. Freshwater concentrations were about 0.8 ug Hg/l and 0.7 ug Se/l. Sediments contained 500 ug Se/kg dry wt. Results showed that human metabolism of mercury is different from selenium metabolism and that selenium retention in man could be influenced by mercury intake. A great part of selenium introduced through the diet passes into the blood, where it is mainly associated with blood cells.

2852. Schell, W.R. and A. Nevissi. 1977. Heavy metals from waste disposal in Central Puget Sound. Environ. Sci. Technol. 11:887-893.

One source of Pb, Cd, Zn, Hg, Cu and Ni in the Puget Sound is liquid effluent from the Metropolitan Seattle sewage treatment facility which is discharged through diffusers at West Point, Seattle, Washington. Heavy metals were measured in water, biota, and sediments collected at various distances from the sewage treatment plant. There were few seasonal differences between amounts and kinds of metals in samples collected near the outfall and at control stations. Concentrations of metals in Puget Sound water, except Pb and Cd, were similar to reported values for open ocean. Metal levels in Puget Sound were 0.1 to

0.8 ug Cd/l, 0.03 to 1.3 ug Pb/l, 0.5 to 2.0 ug Cu/l, 5.0 to 15.0 ug Ni/l, and 1.5 to 3.0 ug Zn/l. Intertidal and benthic biota showed only small increases in concentrations at control stations. Mercury and lead content were 3.0 to 7.0 ug Hg/kg dry wt and 1.0 to 1.5 mg Pb/kg in seaweed, Fucus; 5.0 to 10.0 ug Hg/kg and 1.0 to 2.0 mg Pb/kg in seaweed, Ulva; 6.0 to 12.0 ug Hg/kg and 1.5 to 2.2 mg Pb/kg in mussels, Mytilus edulis; and 5.0 to 12.0 ug Hg/kg and 1.2 to 2.2 mg Pb/kg in clams. Mean metal concentrations, in mg/kg dry wt, in surface sediments were 12 to 21 for Co, 42 to 60 for Cr, 30 to 52 for Cu, 0.27 to 0.70 for Hg, 35 to 50 for Ni, 10 to 50 for Pb, and 90 to 130 for Zn. Sediment cores dated by Pb-210 techniques provided information on the history of metal accumulation in Puget Sound over the past 100 years. Concentrations of several metals at the surface are 1-3.6X greater than in sediments deposited 50 years ago, notably Pb and Hg near West Point.

2853. Schipp, R. and F. Hevert. 1978. Distribution of copper and iron in some central organs of Sepia officinalis (cephalopoda). A comparative study by flameless atomic absorption and electron microscopy. Marine Biology 47:391-399.

In juvenile and adult S. officinalis (a decapod mollusc) of the Bassin d'Arcachon, France, copper and iron contents of blood, hepatopancreas, branchial gland, branchial heart, branchial heart appendages, heart ventricle, and pancreatic appendages were determined. Despite significant differences between the absolute values of Cu and Fe concentrations in different organs, a certain parallelism can be demonstrated in ability to concentrate both metals. The hepatopancreas, as the most important storage organ, shows the highest concentrations of copper (100 mg/kg wet wt) and iron (152 mg/kg), followed by the branchial heart system with distinctly lower values (20 Cu, 46 Fe). The cytolysosome-like dense bodies in these tissues of S. officinalis and of Octopus vulgaris can be characterized as the cellular sites of storage by histochemistry and electron microscopy. The low copper content of branchial gland (22 mg Cu/kg wet wt) does not disprove hemocyanin synthesis in this organ; biochemical experiments indicate a subsequent incorporation of copper released by the endoplasmic reticulum of the gland.

2854. Schulz, D. 1975. Salinitatspraferenzen bei Glasaalen und jungen Gelbaalen (Anguilla anguilla). Helgol. wiss.

Meeresunters. 27:199-210. (In German, English summary).

Preference experiments have been carried out on elvers and young eels to assess locomotory responses to different salinity conditions. It was established that elvers preferred freshwater to water of 18 o/oo and 36 o/oo S. There was no significant difference between responses to water of 18 o/oo and 36 o/oo S. When young yellow eels were offered different salinities (freshwater, 18 o/oo and 36 o/oo S) in tubes, a preference for water of 18 o/oo S was noted. This preference was not influenced by the different salinities in which the eels had previously been kept.

2855. Shephard, K. and K. Simkiss. 1978. The effects of heavy metal ions on Ca^{2+} ATPase extracted from fish gills. Comp. Biochem. Physiol. 61B:69-72.

Gills of the freshwater fish *Rutilus rutilus* contain a subcellular membrane fraction which is rich in the enzyme Ca^{2+} ATPase. The enzyme is maximally activated by Ca^{2+} or Mg^{2+} ions at a concentration of about 2 mM but is not affected by Na^{+} or K^{+} ions or by ouabain. *In vitro* the enzyme is inhibited by Cu^{2+}, Pb^{2+}, Zn^{2+} and Hg^{2+} ions at concentrations below 10 uM. Copper ions at concentrations below 0.2 uM appear to induce the formation of additional enzyme units when applied to fish gills *in vivo*.

2856. Singer, P.C. 1977. Influence of dissolved organics on the distribution, transport, and fate of heavy metals in aquatic systems. *In*: Suffet, I.H. (ed.). Fate of pollutants in the air and water environments. part I. mechanism of interaction between environments and mathematical modeling and the physical fate of pollutants. Advan. Environ. Sci. Tech. 8:155-182.

The influence of dissolved organic matter on distribution, transport, reactivity, and fate of metals in natural aquatic systems is discussed, with examples of Al, Ca, Cd, Co, Cu, Fe, Mg, Mn, Ni, Pb, Po, Si, Zn, and Zr in water, sediments, and algal species. Water quality literature is reviewed using field observations of occurrence and distributions of metals and organics in aqueous environments and phenomenological studies of metal-organic interactions.

2857. Sunda, W.G., D.W. Engel, and R.M. Thuotte. 1978. Effect of chemical speciation on toxicity of cadmium to grass shrimp, Palaemonetes pugio: importance of free cadmium ion. Environ. Sci. Technol. 12:409-413.

Seawater at salinities of 4 to 29 o/oo, with different concentrations of the chelator nitrilotriacetic acid (NTA), were used to determine relationships between chemical speciation of cadmium and Cd toxicity to grass shrimp. After 4 days exposure to a given $CdCl_2$ concentration, shrimp mortality decreased with increasing salinity and increasing NTA concentration. The protective effect of NTA was attributable to complexation of cadmium. In seawater at 4.4 o/oo S, only 0 to 10% of shrimp survived in 246 to 997 ug Cd/l, while 90% survived in 997 ug/l at 29 o/oo S. At 5.2 o/oo S, survival dropped below 50% in 224 ug Cd/l with no NTA, in 448 ug Cd/l with 10 uM NTA, and in 3360 ug Cd/l with 100 uM NTA. Mortality was related to measured free Cd ion concentration, which was determined by total Cd concentration and level of complexation by either Cl ion or NTA. Fifty percent mortality occurred at a free Cd ion concentration of 44.8 ug/l.

2858. Vlasblom, A.G., K.F. Vaas, and W. Rozing. 1977. The osmotic concentration of the blood plasma of plaice (Pleuronectes platessa) from three habitats of different salinity. Netherlands Jour. Sea Research 11:168-183.

Between August 1971 and December 1973, osmotic concentrations of blood plasma of plaice from Lake Grevelingen and Lake Veere, Netherlands, were compared with plaice from the North Sea. Salinity of the sea was always higher than the lakes, of which Lake Veere was lowest. Plaice were hyposmotic to surrounding sea or brackish water. Blood osmotic concentration usually decreased with increasing length of plaice. Influence of temperature on osmotic concentration was stronger in plaice from the North Sea than from either lake. Seasonal fluctuations in plasma osmolarity are more pronounced in North Sea plaice although temperature at sea fluctuated less. Interaction of temperature and salinity changed with fish body length and was strongest in fish from North Sea and weakest from Lake Verre. Authors concluded that plaice that have lived for a longer time in an unusual environment of abnormal salinity (Lake Veere) show the weakest reaction to environmental changes.

2859. Wentsel, R., A. McIntosh, and V. Anderson. 1977. Sediment contamination and benthic macroinvertebrate distribution in a metal-impacted lake. Environ. Pollution 14:187-193.

Sediment contamination and distribution of benthic annelids and insects were studied in Palestine Lake, Indiana, a public 80-ha system contaminated by effluents from a nearby electroplating plant. Trace metal levels in the upper 3 cm of sediment ranged from a high of 969 mg/kg cadmium, 14,032 mg/kg zinc and 2106 mg/kg chromium (dry wt basis) near the influent ditch, to a low of 4 mg/kg Cd, 139 Zn and 38 Cr in the uncontaminated eastern basin of the lake. The midge Chironomus tentans was absent from areas of highest contamination; however, midge numbers increased to an average of 28 individuals/grab sample in the eastern basin. Specimens of the aquatic oligochaete Limnodrilus sp. were abundant (89/sample) in the most heavily impacted areas of the lake and scarce (3.4/sample) in the eastern basin.

2860. Wickes, M.A. and R.P. Morgan, II. 1976. Effects of salinity on three enzymes involved in amino acid metabolism from the American oyster, Crassostrea virginica. Comp. Biochem. Physiol. 53B:339-343.

Adductor muscle and gill tissue from oysters raised in various salinities were assayed for glutamate dehydrogenase (GDH), pyruvate kinase (PK) and glutamate-oxaloacetate transaminase (GOT). GOT increases linearly with salinity in both muscle and gill tissue. GDH increases with salinity in muscle. Little GDH activity is present in gill. No relationship between PK activity and salinity was evident.

2861. Witte-Maas, E.L.M. and D.H. Spaargaren. 1977. Some lethal and sub-lethal effects in Crangon crangon at experimental K^+ enrichment of their environment. Netherlands Jour. Sea Research 11:316-324.

Sudden changes in environmental potassium levels were harmful to shrimps, C. crangon. In 30 o/oo S and 20 C, survival dropped below 50% under the following conditions: 24 hrs in 630 mg K^+/l as KCl; 7 days in 320 mg K^+/l; and 11 days in 160 mg K^+/l. Lethal half-times (LT-50) of Crangon at 5 C decreased from 20 days with no added K^+ at salinities from 10 o/oo to 35 o/oo to 1-5 days in 630 mg K^+/l. Lowest LT-50's were at 10-15 o/oo S, and 30 o/oo. LT-50 values in 20 C were 10-15 days at

10-15 o/oo S and 30 o/oo in 0.0 mg K^+/l, and below 2 days at all salinities in 630 mg K^+/l. Expected LT-50 values calculated from 30 combinations of salinity and potassium concentrations showed shrimps were more sensitive at salinities below 15 o/oo and above 30 o/oo in given K^+ levels in 5 C and 20 C water. Potassium concentrations in blood of shrimps closely paralleled external K^+ levels above 500 mg/l in 20 C, but were hypoosmotic in 5 C. No clear response in heart beat rate of Crangon due to K^+ concentration was observed; heart beat increased slightly in crabs, Carcinus maenas, in raised K^+ water levels.

2862. Yeo, A.R. and T.J. Flowers. 1977. Salt tolerance in the halophyte Suaeda maritima (L.) Dum.: interaction between aluminum and salinity. Ann. Bot. 41:331-339.

Growth of the estuarine plant Suaeda maritima was stimulated by low aluminum concentrations of 1.35 mg/l in saline solution culture containing 19,700 mg NaCl/l. Number and extent of lateral roots increased over 5 days under the same conditions. Under non-saline conditions the same Al concentration inhibited growth and led to an abnormal lateral root initiation. Increasing the level of Al up to 16 mg/l led to growth inhibition under both culture conditions. Salinity reduced the uptake of Al into plant tissue at all levels of Al exposure, and there was no evidence that Al was tolerated internally. Plants in 1.0 mg Al/l accumulated 0.75 mg Al/kg in roots and 0.081 mg Ag/kg in shoots under saline conditions, compared to 1.59 and 0.24, respectively, when grown without NaCl. Although short-term P-32 influx was increased by Al, there were no long-term effects on levels of Na, K, Ca or P in the shoots. Mechanisms of Al toxicity and interaction between Al and salt toxicities are discussed. An explanation is proposed for both stimulatory and inhibitory effects of Al as a quantitative expression of a single primary effect upon the root system.

2863. Yousef, Y.A. and E.F. Gloyna. 1977. A transport model for long term release of low level radionuclide solutions into a stream ecosystem. In: Suffet, I.H. (ed.). Fate of pollutants in the air and water environments. Part 2. chemical and biological fate of pollutants in the environment. Advan. Environ. Sci. Tech. 8:239-259.

Processes of radionuclide transport in flowing water bodies were simulated in small scale ecosystems. Stratification, deposition, erosion, and relocation indicate the complexity of a real river system. Under continuous release of cesium-134 and strontium-85, bottom sediments and plants concentrated radioactivity until an equilibrium state was reached. Transfer coefficients per day from water to sediments were 0.033 to 0.043 for Cs-134 and 0.030 to 0.036 for Sr-85. In rooted plants Potamogeton, Vallisneria, Myriophyllum, Utricularia, and Chara; transfer coefficients were 0.696 for Cs-134 and 0.912 for Sr-85. Plants reached equilibrium faster than sediments. Uptake rate was proportional to the differences between saturation level and concentration in sediments or plants at a given time. Release of radioactivity was observed after cessation of exposure. Cyclical diurnal uptake of Cs-134 by phytoplankton was linearly correlated with photosynthetic O_2 production. Suspended phytoplankton tends to deposit on plant leaves, stems and bottom sediments, suggesting increases in surface concentration attributable to area of sorbing surfaces.

2864. Augier, H., G. Gilles and G. Ramonda. 1978. Studies on the mercury content in the thallus and in a commercial product of agricultural use of the brown algae Ascophyllum nodosum (Linne) Le Jolis manufactured in Brittany. Botanica Marina XXI:413-416. (In French, English abstract).

Whole brown algae collected in 1977 from Brittany contained 0.07 to 0.11 mg Hg/kg wet wt; concentrations in different sections of the thallus of Ascophyllum ranged from 0.07 to 0.14 mg Hg/kg. Commercially prepared algal products had a mean mercury level of 0.08 mg/kg. Local seawater contained 0.0002 mg Hg/l.

2865. Bacci, E., C. Leonzio, and A. Renzoni. 1978. Mercury decontamination in a river of Mount Amiata. Bull. Environ. Contamin. Toxicol. 20:577-581.

Since 1970, there has been a drastic reduction in mining of mercury-bearing minerals around Mount Amiata, Italy. In 1969, by comparison, a total of 1680 metric tons of mercury were produced. Freshwater mussels, Unio elongatulus, collected in 1973 contained 0.75 to 1.60 mg Hg/kg wet wt in abductor muscle, with highest concentrations in larger animals. By 1974, mercury levels of abductor muscle had dropped to 0.5 to 0.8 mg/kg; and by 1975 and 1976 concentrations were 0.05 to 0.25 mg/kg. These latest values determined are only about twice that of background levels in control site mussels (0.03 to 0.07 mg Hg/kg wet wt).

2866. Boggess, W.R. (ed.). 1977. Lead in the environment. Nat. Science Foun. Rept. NSF/RA-770214:272 pp. Avail. from Supt. Documents U.S. Govt. Print. Off., Washington, D.C. 20402.

This study of lead in the environment summarizes data on characteristics, monitoring, and analysis of lead: transport and distribution in atmosphere, soil, biota, watersheds, and around mines and smelters; effects of lead on microorganisms, plants, animals, and humans; and recommendations for control. Several studies of freshwater ecosystems deal with lead levels in sediments, fish, benthic invertebrates (including insects, crustaceans, molluscs, annelids, and nematodes), bacteria, algae, and higher plants and effects of Pb on biota.

2867. Christensen, G., E. Hunt, and J. Fiandt. 1977. The effect of methylmercuric chloride, cadmium chloride, and lead nitrate on six biochemical factors of the brook trout (Salvelinus fontinalis). Toxicol. Appl. Pharmacol. 42:523-530.

Brook trout were exposed to methylmercuric chloride at concentrations from 0.01 to 2.93 ug of Hg/l, to cadmium chloride from 0.06 to 6.35 ug of Cd/l, and to lead nitrate from 0.90 to 474.0 ug of Pb/l, for 2- or 8-week periods. Fish weight and length, hemoglobin, and blood plasma sodium, chloride, glucose, glutamic oxalacetic transaminase (GOT), and lactic dehydrogenase (LDH) were measured. The following observed changes were significant: increases in plasma sodium and chloride and decreases in hemoglobin and GOT activity caused by Pb at a threshold of 58 or 235 ug/l; increases in plasma chloride and LHD and a decrease in plasma glucose caused by Cd at a minimum of 6.35 ug/l; and increases in hemoglobin and plasma sodium and chloride caused by 2.9 ug/l of methylmercury. Comparisons were made between these biochemical findings and published data from bioassay and tissue-residue studies regarding the determination of threshold indices of toxicity. Maximum acceptable concentration indices, in ug/l, for brook trout were: molecular index for no biochemical change in adults, 0.94 (2 wk) and 2.9 (8 wk exposure) for Hg, 6.4 and 0.5, respectively, for Cd, and 0.5 and 34.0 for Pb. Maximum acceptable concentrations bioassay index for no mortality, growth change, or deformities for alevin-fry and adults exposed for 38 wks, were: 0.29 Hg, 1.7 Cd, and 58.0 Pb. The residue index showing no increasing deposition in body for adults exposed 38 wks; 0.01 Hg, 0.5 Cd, and 0.9 Pb. Maximum allowable water concentrations for freshwater biota, in ug/l, as suggested by the U.S. Environmental Protection Agency, are 0.05 Hg, 0.4 Cd and 50.0 Pb.

2868. D'Itri, F.M., A.W. Andren, R.A. Doherty and T.M. Wood. 1977. An assessment of mercury in the environment. Panel on Mercury Coord. Comm. Sci. Tech. Assessments Environ. Pollutants. Nat. Acad. Sciences, Nat. Research Coun., Washington, D.C.:183 pp.

This report summarizes data on the global cycle of mercury, forms and occurrence of mercury in the environment, chemical and biochemical mechanisms for methylation and demethylation, ecological effects to biota, and exposure, uptake, and effects of mercury on humans. Ecological effects reviewed include uptake, retention, and elimination in freshwater and marine species of algae, higher plants, zooplankton, insects, crustaceans, molluscs, fish, amphibians, birds, and mammals. Data on exposure and uptake of mercury in humans via food, including fish and other seafood, drinking water, and air, and various effects of methylmercury to adult populations, fetuses, and human biological processes are also presented. A bibliography of approximately 400 references is appended.

2869. Fahy, W.E. and R.K. O'Hara. 1977. Does salinity influence the number of vertebrae developing in fishes? Jour. Conseil Int. Explor. Mer 37:156-161.

Embryos of the cyprinodontid fish, Fundulus majalis, were reared from gastrulation to hatching in a controlled temperature room at five different salinities (16, 21, 26, 31, and 36 o/oo). Comparisons of mean vertebral counts show no statistically significant differences occurring between groups; thus no salinity influence upon vertebral number is indicated. Literature on salinity influence upon vertebral number in fishes is reviewed. It is concluded that there is little evidence, from field or laboratory studies, to support the view that salinity can modify vertebral number in developing fishes.

2870. Fowler, S.W. and M.Y. Unlu. 1978. Factors affecting bioaccumulation and elimination of arsenic in the shrimp Lysmata seticaudata. Chemosphere 9:711-720.

Concentration factors (CF) of radioarsenic-74 as sodium arsenate in tissues of shrimp following 8 days exposure in media containing 2 to 100 ug As/l were: 2.6 to 2.7 in whole animal, 5.2 to 8.0 in exoskeleton, 1.3 to 4.4 in muscle, and 3.0 to 4.2 in viscera. In general, smaller individuals had the largest CF. Exoskeleton and muscle contained most of the As-74 accumulated in tissues. Exoskeleton and muscle contained 41% and 42%, respectively, of body total after 8 days; and 52% and 31% after 14 days. After 7 days depuration following 6 day exposure, exoskeleton contained 34% of total As-74 and muscle 42%. After 35 days loss following single ingestion of As from labelled Artemia, 30% of As was in exoskeleton and 48% in muscle. Molting caused large variations in As accumulation: shrimp lost about 60% of incorporated As-74 at each molt. Arsenic accumulation decreased with increasing salinity from 16 to 38 o/oo. Molting masked any temperature effects since shrimp molted faster at higher temperatures. Loss of As-74 was slower when accumulated from food than water, being slightly faster at 20 C than 10 C. Exposure salinity had little effect on As retention.

2871. Hamelink, J.L., R.C. Waybrant, and P.R. Yant. 1977. Mechanisms of bioaccumulation of mercury and chlorinated hydrocarbon pesticides by fish in lentic ecosystems. In: Suffet, I.H. (ed.). Fate of pollutants in the air and water environments. part 2. chemical and biological fate of pollutants in the environment. Adv. Environ. Sci. Tech. 8:261-281.

Bioaccumulation of mercury, lindane, and DDE by rainbow trout, Salmo gairderi, in a flooded limestone quarry in southern Indiana has been studied for over 3 yrs since additions of 5.0 ug Hg/l as mercuric nitrate and 0.05 ug/l of both pesticides in summer 1972. Water concentration of mercury dropped to 0.15 ug/l by 120 days, about the time trout were added. Fish accumulated mercury faster than DDE over 350 days; lindane body burden increased only slightly. Uptake efficiency from water by fish for organic methylmercury approached 20%, while for inorganic forms it was only 0.2%. Another source of mercury for trout was via zooplankton diet, primarily Daphnia, which contained 360 ug Hg/kg. Total mercury available to trout from water and food was 94 ug organic Hg/l or kg and 62 ug inorganic, of which 39 and 26 ug/kg, respectively, were retained by fish during 350 days of exposure.

2872. Hammons, A.S., J.E. Huff, H.M. Braunstein, J.S. Drury, C.R. Shriner, E.B. Lewis, B.L. Whitfield, and L.E. Towill. 1978. Reviews of the environmental effects of pollutants: IV. cadmium. U.S. Environ. Protect. Agency Rept. EPA-600/1-78-026:253 pp. (also listed as Oak Ridge Nat. Lab. Rept. ORNL/EIS-106). Avail. from Nat. Tech. Inform. Serv., Springfield, VA 22161.

Health and environmental effects of cadmium and specific cadmium derivatives are reviewed. More than 500 references are cited. Background levels of cadmium are typically low. The highest concentrations are most likely to be found near smelters or industrialized urban areas. Cadmium is introduced into the environment mainly during extraction, refining, and production of metallic cadmium, zinc, lead, and copper; through wastes generated during other metallurgical processes such as electrolytic plating; through reprocessing of scrap metal such as cadmium-plated steel; following disposal by combustion; or as solid wastes from consumer items such as paints, nickel-cadmium batteries, and plastics. Other sources of cadmium in the environment are cadmium-containing fungicides, phosphate fertilizers, and municipal sewage sludges. The cadmium body burden in animals and humans results mainly from diet. In the United States, the normal intake of cadmium for adult humans is estimated at about 50 ug/day. Tobacco smoke is a significant additional source of cadmium exposure. The kidneys and liver together contain about 50% of the total cadmium body burden. Acute cadmium poisoning is primarily an occupational problem, generally from inhalation of cadmium fumes or dusts. In the general population, poisoning by inhaled or ingested cadmium or its compounds are relatively rare. Biological aspects of uptake, metabolism, distribution, and effects of cadmium in aquatic bacteria, algae, higher plants, protozoans, crustaceans, molluscs, annelids, fish, and birds, and interactions with copper, zinc, and salinity are reviewed. The major concern about environmental cadmium is the potential effects on the general population. There is no substantial evidence of hazard from current levels of cadmium in air, water, or food. However, because cadmium is a cumulative poison and because present intake provides a relatively small safety margin, authors believe there are adequate reasons for concern over possible future increases in background levels.

2873. Jones, J.B. and T.C. Stadtman. 1977. Methanococcus vanniellii: culture and effects of selenium and tungsten on growth. Jour. Bacteriology 130:1404-1406.

Reisolation, culture, and method of preservation of the methane-producing anaerobe Methanococcus vannielii isolated from mud of San Francisco Bay is described. Growth of the organism on formate was markedly stimulated by selenium and tungsten. Turbidity of the bacterial culture, as a measure of growth, was 3X higher in 79 ug Se/l as selenite than controls at 100 hrs, and 5X higher in 79 ug Se/l plus 18,380 ug W/l as tungstate. Cell yields were 760 mg wet wt/l in controls, 1000 mg/l in Se, and 1100 mg/l in Se plus W.

2874. Jones, R.M. and S.S. Hillman. 1978. Salinity adaptation in the salamander *Batrachoseps*. Jour. Exp. Biol. 76:1-10.

Relatively few species of amphibians can tolerate salinites above 300 m-osmol on a sustained basis. However, *Batrachoseps attenuatus* and *B. major* were successfully acclimated to 600 m-osmol NaCl and 400 m-osmol sucrose solutions. Accumulation of sodium over 5290 mg/l and an increased rate of urea synthesis in excess of 200 mM provided substantial increases in plasma concentrations of these solutes; these are probably the two major solutes (plus anions) responsible for elevation of osmotic concentration in *Batrachoseps*. *Batrachoseps* exhibits a water balance response upon dehydration. Urine production was significantly reduced in salamanders acclimated to sucrose solutions compared to those acclimated to tap water or saline of equivalent osmotic concentration. Plasma urea concentration was equivalent to urine urea concentration when *Batrachoseps* was kept in tap water and during short-term saline acclimation. After long-term saline acclimation, urine urea concentration was one-fourth the plasma urea concentration.

2875. Karpevich, A.F. and A.T. Shurin. 1977. Manganese in the metabolic processes of mollusks of the Baltic Sea. Soviet Jour. Marine Biology 3:437-442.

The effect of Mn^{2+}, as $MnCl_2$, on metabolic processes of *Macoma baltica*, *Mya arenaria*, and *Dreissena polymorpha*, in the Gulf of Riga, was studied. In concentrations of 2-5 mg/l, accumulation of manganese in gonad, liver, and heart of molluscs was low. Oxygen consumption rose sharply in 17-20 mg Mn/l. After 30-50 days in 30 to 50 mg Mn/l, average tissue contents rose to 1000-19,300 mg Mn/kg dry wt in mantle (*vs.* 1.0-270.0 in controls), 50-13,000 in gills (1.0-20.0 controls), 120-1000 in liver (5.0-50.0 controls), and 30-290 in foot (1.0-3.0 controls). As Mn concentration was increased to 140 mg/l, oxygen consumption gradually declined, the animals became moribund and died. After about 2 months in solutions of 2-17 mg Mn/l, molluscs' shells became overgrown with bacteria and blackened as the result of excretions of grains containing manganese.

2876. Levander, O.A. (Chmn.). 1976. Arsenic. Subcomm. Arsenic, Comm. Med. Biol. Eff. Environ. Pollutants, Nat. Res. Coun. Nat. Acad. Sciences, Washington, D.C.:480 pp.

A review of arsenic is presented with emphasis on chemistry, distribution in the environment (air, water, soil, sediments, and biota), metabolism, and biologic effects on plants, animals, and man. Control recommendations are made by the authors. Arsenic concentrations in plants, plant products, and animals are listed, including data on algae and aquatic plants, mammals (humans and whales), crustaceans (shrimps, crawfish, lobsters, crabs, and plankton), molluscs (bivalves, shelled gastropods, squid, and octopus), echinoderms (starfish), and a variety of freshwater and marine fishes. Authors conclude that environmental contamination of arsenic and subsequent human exposure to various arsenic compounds has resulted from air pollution from smelters, improper use of arsenic pesticides, and episodes of tainted food and drink. Water supplies generally contain negligible quantities of As, although some cases of endemically poisoned waters are reported. A bibliography of over 800 references is included.

2877. MacInnes, J.R. and A. Calabrese. 1978. Response of the embryos of the American oyster, Crassostrea virginica, to heavy metals at different temperatures. In: McLusky, D.S. and A.J. Berry (eds.). Physiology and behaviour of marine organisms. Pergamon Press, New York:195-202.

LC-50 (48 hr) values of mercury, silver, zinc, and copper salts to Crassostrea embryos at 20, 25, and 30 C were 10.2 to 12.6 ug Hg/l, 24.2 to 35.3 ug Ag/l, 205 to 324 ug Zn/l, and 15.1 to 18.7 ug Cu/l. All metals, added either individually or in combination, were less toxic at 25 C than 20 or 30 C, suggesting that oyster embryos are more susceptible to metal toxicity at either 20 or 30 C. Less-than-additive effects were observed at 20 and 25 C with mercury and silver in combination. Simple additive effects were noted at 30 C for the mercury-silver mixture and at 20, 25, and 30 C for the copper-zinc mixture.

2878. Middaugh, D.P. and G. Floyd. 1978. The effect of prehatch and posthatch exposure to cadmium on salinity tolerance of larval grass shrimp, Palaemonetes pugio. Estuaries 1:123-125.

Exposure to 0.1 or 0.3 mg/l cadmium at 30 o/oo salinity for 1, 4, or 8 days prior to hatching had no additive effects on sensitivity of larval shrimp to subsequent Cd exposure and salinity stress for 14 days after emergence. Only larvae exposed to 0.1 mg Cd/l for 4 days before hatching and transferred to 10 o/oo S water with 0.1 mg Cd/l after hatching had significantly decreased survival. No decreases were observed for larvae transferred to 15 and 30 o/oo at a pre- and posthatch cadmium concentration of 0.1 mg/l. At a pre- and posthatch concentration of 0.3 mg Cd/l, survival was reduced for all larvae transferred to 10 and 15 o/oo S after hatching. Significant mortality occurred for only 2 groups exposed before hatching and transferred to 30 o/oo S and 0.3 mg Cd/l during 14 days after hatching.

2879. Moller, V.W. 1978. Lead contents of freshwater snails in the Upper Rhine Valley. Arch. Hydrobiol. 83:405-418. (In German, English abstract).

Lead in gastropods collected from the northern Upper Rhine Valley in spring and summer 1975 was analyzed. Mean concentrations, in mg Pb/kg dry wt, in whole animals were 66.1 for Lymnaea ovata, 72.8 for L. stagnalis, 93.6 for Galba truncatula, 68.1 for Planorbis corneus, 75.8 for P. planorbis, 70.0 for Physa acuta, 71.6 for Anisus vortex, and 59.0 for Bithynia tentaculata. Highest tissue concentrations were registered in shells, averaging 54.3 to 81.0 mg Pb/kg. The lead content of snails collected near busy roads was exceptionally high, when compared to an isolated district far from heavy traffic. Increased lead was observed in summer 1975, and was apparently related to increased traffic activity. There was no obvious correlation between Pb content and body size or species. In general, shell contained more than half the total body content followed by viscera, foot, and mantle in that order.

2880. Moraitou-Apostolopoulou, M. 1978. Acute toxicity of copper to a copepod. Marine Poll. Bull. 9:278-280.

Acute toxicity of copper to the marine copepod, Acartia clausi, from two locations, one polluted with industrial effluents and domestic wastes and another from a relatively uncontaminated area, were compared. LC-50 (48 hr) value for uncontaminated copepods was 0.034 mg Cu/l, while for contaminated populations it was 0.082 mg Cu/l. All copepods from the uncontaminated area died within 24 hrs in 1.0 mg Cu/l; all from the contaminated area died after 72 hrs. No copepods died within 24 hrs in up to 0.05 mg Cu/l from contaminated populations. However, 15 to 28% from uncontaminated populations died in 0.01 to 0.05 mg Cu/l.

2881. Olsson, M. 1976. Mercury levels in biota from Morrum River during a 10 year clean-up period. Rep. Inst. Freshwater Res. Drottningholm 55:71-90.

Mercury levels in biota from 11 localities along the Morrum River, Sweden, after mercury discharge from a paper mill had ceased, were analyzed each year since 1965. Mean mercury levels, in ug/kg dry wt, in organisms collected above the mill since 1969 were: 90 to 125 in alderfly larvae *Sialis lutaria*, watermoss *Fontinalis antipyretica*, and caddisfly larvae *Hydropsyche pelucidula* and *H. instabilis*; 140 to 160 in dragonfly larvae *Agrion splendens* and adult *A. imagines*, leeches belonging to Erpobdellidae, and fry of fishes, *Gobis gobis*, roach *Rutilus rutilus*, and pike *Esox lucius*; and 275 in isopods *Asellus aquaticus*. Mercury concentrations, in ug/kg wet wt, in these organisms at sites below the mill decreased from about 500-11,000 in 1965 to 20-200 in 1974. Generally, Hg levels dropped exponentially and the maximum decrease was seen in biota closest to the mill. Mercury content in muscle of roach below the paper mill decreased from 1250 to 350 ug/kg wet wt during 1968 to 1974; maximum levels in 1971 were found in fish furthest downstream from the mill. Concentrations in breast muscle of birds, white wagtail, were <200 ug/kg upstream and 300 to 800 downstream from the mill. Author concluded that mercury levels were not correlated with food or habitat of the different species; that ratios between Hg levels in 8 species was the same in contaminated and uncontaminated areas; that invertebrate Hg levels depend on intake of water and possibly metabolic rate; that decrease in Hg concentration below the mill was exponential with time; that time for 50% decrease varied from 1 to 2.5 years in invertebrates and fish; that during discharge, highest levels were found close to the mill, while after discharge ceased, high levels were further downstream possibly due to sediments becoming the pollution source; and that elevated Hg levels in birds downstream showed the influence on terrestrial organisms from aquatic insects.

2882. Roth, I., and H. Hornung. 1977. Heavy metal concentrations in water, sediments, and fish from Mediterranean coastal area, Israel. Environ. Sci. Technol. 11:265-269.

Water, sediment, and biota were collected along the northern part of the Mediterranean coast of Israel in 1974 and analyzed for cadmium, lead, copper, zinc, nickel, and chromium. Values showed no significant heavy metal pollution in the studied area, compared with values found in literature for metal concentrations in other parts of the world. Mean water metal levels off Israel, in ug/l, were 0.7 to 0.9 for Cd, 2.0 to 2.8 for Cu, 2.8 to 3.6 for Ni, 6.8 to 7.2 for Pb, and 30 to 44 for Zn. Metal concentrations in particulate matter were 0.2 ug Cd/l, 0.4 Cr, 0.4 Cu, 0.5 Ni, 2.4 Pb, and 5.7 Zn. Average sediment concentrations were 0.7 mg Cd/kg dry wt, 4.2 for Cr, 1.6 for Cu, 4.8 for Ni, 8.4 for Pb, and 7.0 for Zn. Marine chlorophytic and rhodophytic algae contained 0.9 to 2.1 mg Cd/kg dry wt, 2.6 to 6.7 for Cr, 2.9 to 7.6 for Cu, 5.2 to 5.8 for Ni, 1.9 to 22.2 for Pb, and 117 to 218 for Zn. Commercial fishes *Sardinella aurita*, *Saurida undosquamis*, *Merluccius merluccius*, *Epinephelus guaza*, *Mullus barbatus*, *Upeneus moluccensis*, *Diplodus vulgaris*, *Sphyraena sphyraena*, *Siganus rivulatus*, and *Solea solea* contained means of 0.1 to 0.7 mg Cd/kg dry wt, 0.6 to 4.9 for Cr, 0.7 to 8.3 with a high of 23.5 for Cu, 0.1 to 10.8 for Ni. 0.04 to 5.3 for Pb, and 0.5 to 40.2 with highs of 61 to 84 for Zn.

2883. Towle, D.W., M.E. Gilman and J.D. Hempel. 1977. Rapid modulation of gill Na$^+$+K$^+$-dependent ATPase activity during acclimation of the killifish *Fundulus heteroclitus* to salinity change. *Jour. Exp.* Zoology *202:179-186.*

Enzymatic properties of membrane-bound Na$^+$+K$^+$-ATPase from gills of killifish acclimated to freshwater, to 16 o/oo seawater, or to 30 o/oo seawater appeared to be identical, indicating that the same enzyme may function to absorb Na$^+$ in low salinities and excrete Na$^+$ at the gills in high salinities. Specific activities of Na$^+$+K$^+$-ATPase in the three salinities were consistent with expected Na$^+$ pumping rates; activity was higher in freshwater and 30 o/oo S than in 16 o/oo S. Within 30 min after transfer of killifish from one salinity to another, gill Na$^+$+K$^+$-ATPase activities reached equilibrium. Rapid increase in Na$^+$+K$^+$-ATPase activity in gill microsomes of fish acclimating from freshwater to 30 o/oo was accompanied by a slow decrease in the number of binding sites for ouabain, supporting the idea that acclimation to short-term salinity changes may involve modifications in the catalytic rate rather than the number of Na$^+$+K$^+$-ATPase molecules.

2884. Amiard-Triquet, C. and L. Foulquier. 1978. Modalites de la contamination de deux chaines trophiques dulcaquicoles par le cobalt 60: I: contamination directe des organismes par l'eau. Water, Air, Soil Pollution 9:475-489. (In French, English abstract).

Cobalt-60 transfer through two freshwater food chains were investigated using *Chlorella* (algae) → *Daphnia* (cladoceran) → carp (fish); and *Elodea* (macrophyte) → *Lymnaea* (gastropod) → crayfish (crustacean). Peak values for Co-60 accumulation (mean concentration factor from water) was 24 hrs (565) for *Chlorella*, 32 days (3.4) for carp, 30 days (4200) for *Elodea*, about 5 wks (about 700) for *Lymnaea*, and about 6 wks (about 220) for crayfish. In general, the most highly contaminated species were the primary elements in the food chain. Authors concluded that concentration factors obtained under laboratory conditions were of limited worth for extrapolation to field situations.

2885. Anderson, R.V. 1978. The effects of lead on oxygen uptake in the crayfish, *Orconectes virilis* (Hagen). Bull. Environ. Contamin. Toxicol. 20:394-400.

Increased Pb concentrations (from 0.0 to 0.5, 1.0, or 2.0 mg Pb/l) caused some decrease in oxygen consumption of crayfish over a period of 40 days when compared to controls. Crayfish compensated for decreased gill efficiency by increased ventilation volume. Maximum concentrations of Pb recorded, in mg/kg dry wt, were observed at 2.0 mg Pb/l after exposure for 40 days: 52 in exoskeleton, 50 in gill, 12 in viscera, and about 8 in muscle.

2886. Bengtsson, B.E. 1978. Use of a harpacticoid copepod in toxicity tests. Marine Poll. Bull. 9:238-241.

The harpacticoid copepod, *Nitocra spinipes*, was tested for acute toxicity of 12 metal chlorides in brackish water. LC-50 (96 hr) values, in mg/l, were 0.23 for Hg^{2+}, 1.45 for Zn^{2+}, 1.8 for Cd^{2+}, 1.8 for Cu^{2+}, 4.5 for Co^{2+}, 6.0 for Ni^{2+}, 10.0 for Al^{3+}, 21 for Fe^{3+}, 70 for Mn^{2+}, 450 for K^{+}, 580 for Ca^{2+}, and 720 for Mg^{2+}. Their order of toxicity, expressed as 96 hr LC-50, was in agreement with other investigations performed in freshwater and seawater. Brackish water LC-50 (96 hr) values were intermediate to those for fish and seawater environments. Author concludes that *N. spinipes* is a suitable assay organism for brackish water toxicity tests.

2887. Bloom, H., and G.M. Ayling. 1977. Heavy metals in the Derwent Estuary. Environ. Geology 2:3-22.

Analyses of heavy metal concentrations in filtered waters, suspended particulates, sediments, shellfish, fish, airborne particulates, and sewage have confirmed work of other investigators showing that the Derwent Estuary, Tasmania, is heavily contaminated, particularly with mercury, cadmium, lead, and zinc. Analyses also have added information about the distribution of each metal. Apparently, most of the contamination originated from the operation of a zinc refining plant. More than 20 species of molluscs and barnacles growing in contaminated regions were listed in order of their respective abilities to accumulate each heavy metal. Mussels, *Mytilus edulis*, were good indicators of cadmium and mercury contamination, but not zinc. Surf barnacles, *Catophragmus polymerus*, were one of the most sensitive biological indicators of cadmium contamination. An indication of the steps by which a waste metal is eventually accumulated at high and even toxic concentrations in seafoods, may be seen from a comparison of the relative concentrations of cadmium, lead, mercury, and zinc found in mussels, sediments, suspended particulates, and filtered waters. High concentrations recorded for metals include: 1100 mg Hg/kg, 10,000 mg Zn/kg, and 862 mg Cd/kg in dried sediments; 1500 mg Cd/kg in airborne dust fallout; and 16 ug Hg/l, 15 ug Cd/l, and 1500 ug Zn/l in filtered water. Maximum levels in organisms were 200 mg Cd/kg dry wt in oyster *Ostrea angasi*; 152 to 452 mg Pb/kg in *M. edulis* and chiton *Sypharochiton pellis-serpentis*; 3500 to 100,000 mg Zn/kg in *O. angasi*, barnacle *C. polymerus*, and winkle *Dicathais tertilosa*; and 8.2 to 14.6 mg Hg/kg in the molluscs *M. edulis*, *O. angasi*, *Anapella cycladea*, *Percanassa pauperata*, and *Salinator fragilis*. Among 10 local fish species, *Platycephalus bassensis*, *Ruboralgu ergastulorum*, and sharks *Mustilus antarcticus* and *Squalus* sp. contained 0.50 to 0.76 mg Hg/kg wet wt, equal to or above the Tasmanian Public Health Regulations maximum allowable concentration of 0.50 mg Hg/kg.

2888. Bloom, H.D., A. Perlmutter, and R.J. Seeley. 1978. Effect of a sublethal concentration of zinc on an aggregating pheromone system in the zebrafish, *Brachydanio rerio* (Hamilton-Buchanan). Environ. Pollution 17:127-131.

Adult female zebrafish maintained in water containing a sublethal level of 5.0 mg/l zinc for 9 days showed no preference for pheromone-containing donor water at a concentration of pheromone shown to attract non-zinc treated females. The possible effect of Zn interference with the pheronomal sex attractant is discussed.

2889. Boney, A.D. 1978. Marine algae as collectors of iron ore dust. Marine Poll. Bull. 9:175-180.

Five species of intertidal marine algae (*Porphyra umbilicalis*, *Plumaria elegans*, *Polysiphonia lanosa*, *Cladophora rupestris*, *Pelvetia canaliculata*) when shaken in iron ore dust suspensions in seawater (5 g Fe/l) take up appreciable quantities of the dust load. Weight of ore dust retained per kg fresh wt of plant after shaking for 6 hrs was 192 to 198 g for *Plumaria*, 208 to 210 g for *Cladophora*, 50 to 64 g for *Polysiphonia*, and 48 to 49 g for *Pelvetia*. The quantities taken up vary with the modes of thallus construction. Considerable quantities of ore dust are retained by the plants after shaking for up to 15 hrs in dust-free seawater. Marine algae can be used as a monitoring system for ore dust loading of seawater due to accidental spillages in the vicinity of ore unloading terminals.

2890. Brodwick, M.S. and D.C. Eaton. 1978. Sodium channel inactivation in squid axon is removed by high internal pH or tyrosine-specific reagents. Science 200:1494-1496.

In squid axon, internal alkalinization from pH 7.1 to pH 10.2 results in a reversible decrease of the maximum inward current and the steady state sodium channel inactivation. Similar effects were observed after treatment of the axon with tetranitromethane or after iodination with lactoperoxidase. These results suggest that a tyrosine residue is an essential component of the inactivation process in this nerve.

2891. Burgess, B.A., N.D. Chasteen, and H.E. Gaudette. 1975/76. Electron paramagnetic resonance spectroscopy: a suggested approach to trace metal analysis in marine environments. Environ. Geology 1:171-180.

Electron paramagnetic resonance (EPR) spectroscopy analysis of marine samples from different environments appears to differentiate between adsorbed and structural Mn^{2+} and Fe^{3+} sites in sediment. This suggests that EPR may provide a means of distinguishing different environmental influences on sediment. Acid extract solutions from sediment samples exhibit clearly defined EPR spectra due to various metals, which are amenable to qualitative and quantitative analysis at concentrations below 1.0 mg/kg. Spectra of several shellfish vary considerably, both between species, and within a species, depending on sampling localities. Resonances from Mn^{2+}, Mo^{5+}, and Fe^{3+} were obtained from shells of barnacles *Balanus balanoides*, mussels *Mytilus edulis*, brain corals *Maeandrina*, sea urchins

Strongylocentrotus drobackiensis, sea fans Gorgonia flabellum, clams Mya arenaria, and periwinkles Littorina littorina. Mytilus shells from New Hampshire contained approximately 20 mg Mn/kg based on EPR examination; higher levels than reported from other locations. Mn^{2+} is substituted for Ca^{2+} in the calcite structure of some shells, such as Balanus.

2892. Davies, I.M. and J.M. Pirie. 1978. The mussel Mytilus edulis as a bio-assay organism for mercury in seawater. Marine Poll. Bull. 9:128-132.

Surveys of natural populations of mussels have identified areas of mercury contamination in the Firth of Forth, Scotland. A field bioassay technique has been devised which accurately reflects the mean total mercury concentration in the surrounding seawater. The detection limit of the technique is estimated at 5 to 20 ng Hg/l; consequently, the method can detect comparatively small enhancements over background mercury concentrations in estuarine and seawater.

2893. Deitmer, J.W. 1977. Effects of cobalt and manganese on the calcium-action potentials in larval insect muscle fibres (Ephestia kuhniella). Comp. Biochem. Physiol. 58A:1-4.

In either cobalt- or manganese-(5-25 mM) containing solutions, action potentials could be elicited by direct stimulation. The maximal rates of rise and fall of these action potentials were, however, considerably reduced. The repolarization phase of the action potentials was delayed by Co and Mn. The membrane input resistance increased in the presence of Co and Mn (25 mM) by a factor of 2-4, while the membrane rectification was abolished. It is suggested that Co and Mn ions reduced both the inward and outward current of the muscle membrane. Effects of Co and Mn are compared with those described for other excitable cells.

2894. Dickman, M.D. and M.B. Gochnauer. 1978. Impact of sodium chloride on the microbiota of a small stream. Environ. Pollution 17:109-126.

The addition of 1000 mg/l NaCl to a small stream to simulate road salt loading resulted in a reduction in algal density and an increase in bacterial density on artificial substrates left in the stream over a 4-week period. Algal diversity was lower at the salt stressed station, 1.88 compared with 2.49 in week 3, and 2.61 compared with 2.91 at the fourth week. Phytophagous grazers were far more abundant at the salt-free control station. These grazers increased algal diversity by preventing Cocconeis placentula (the dominant alga) from overgrowing and out-competing the other major algal species. Bacterial densities, principally Hyphomicrobium, were significantly higher at the salt-treated station while algal densities on the salt-exposed substrates were significantly lower than on the control slides.

2895. D'Silva, C. and T.W. Kureishy. 1978. Experimental studies on the accumulation of copper and zinc in the green mussel. Marine Poll. Bull. 9:187-190.

Toxicity of copper and zinc to green mussel, Mytilus viridis, was evaluated by short-term bioassays. LC-50 (48 hr) values were 0.14 mg/l for Cu and 2.31 mg/l for Zn. The rates of copper and zinc accumulation were determined by analyzing metal content in soft parts of mussels at fixed intervals of time. Maximum accumulation of Zn (60 mg/kg wet wt) was observed after 5 wks immersion in 0.2 mg Zn/l; for Cu this was ~3.2 mg/kg wet wt after immersion for 5 wks in 0.01 mg Cu/l. Bioaccumulation was determined as a function of metal concentration in the experimental medium. The correlations for the regression lines indicate that uptake of metal is linear at least for the first 5 weeks.

2896. EIFAC Working Party on Water Quality Criteria for European Freshwater Fish with the cooperation of the United Nations Environment Programme (UNEP). 1978. Report on cadmium and freshwater fish. Water Research 12:281-283.

Cadmium is widely used in industry and small quantities are discharged to surface freshwaters. Natural background concentrations are usually below 1.0 ug/l, but higher levels have been found in polluted waters. A substantial proportion of the Cd in river water is adsorbed onto solids in suspension, but only soluble forms of Cd are toxic to fish. Little is known of the toxic action of cadmium to fish. The metal is accumulated predominantly in gills, liver, and kidney. The significance of Cd residues is not clear although there is some evidence that osmoregulatory role of gills and kidney may be impaired. Cadmium is slowly lost from tissues when fish previously exposed to cadmium are returned to clean water; however, loading can occur in a short period of time causing death several days later. Acute and chronic toxicity tests with sensitive species of fish have given conflicting results which may have been caused by the variable and unusual concentration-response curve or errors in measuring concentrations of soluble cadmium. Concentrations lethal after at least 10 days exposure can be up to 100X less than those lethal in 2 to 4 days, and if a threshold lethal concentration exists, it is ill defined. Several environmental factors influence the position and shape of the concentration-response curve. A decrease in water hardness and dissolved oxygen, and possibly in pH value, produces a lower LC-50; changes in temperature and salinity may also affect cadmium toxicity. The sensitivity of different species of fish is more variable for cadmium than for other common pollutants but comparisons between data are difficult to make because of differences in water quality and exposure times. However, of the few species tested, salmonids are more sensitive than cyprinids (with the possible exception of carp), with pike occupying an intermediate position. Juvenile stages appear to be the more sensitive. Few sublethal effects of cadmium have been observed. Minnows have been shown to develop spinal deformities and in rainbow trout the development of ova can be impaired. Increased activity of male brook trout during spawning in low concentrations of cadmium has led to increased mortality. Salmonid fish appear to be more sensitive than other aquatic biota species which have been tested. Some species of invertebrates such as Daphnia magna and Gammarus fossarum appear to be as sensitive as salmonids, but most others are much more resistant. Some species of aquatic plants grow more slowly in concentrations of cadmium which are close to the limits for the survival of fish, but the majority of plants appear to be very resistant. Few data exist on the status of fish fauna in surface waters polluted with cadmium, although there is some evidence that brown trout were absent from waters where cadmium concentration was predicted to be harmful on the basis of laboratory experiments. Minnows were also found at concentrations predicted to be harmless to trout. However, rivers polluted with cadmium also contain other pollutants, especially heavy metals, and although some of these have been shown to be additive with cadmium in their joint toxic action, there is some evidence that zinc may have an antagonistic effect. On the basis of a critical examination of the available data, tentative criteria for dissolved cadmium can be proposed as follows. Values for common carp should be taken to be the same as those for rainbow trout pending further data on long-term effects. The corresponding values for brown trout and pike appear to be about twice as high as those for rainbow trout while those for the more insensitive non-salmonid fish such as perch and minnow would be about 38X higher; allowances should be made for low concentration of dissolved oxygen and for the presence of other poisons. There is a need for reliable field data from polluted and unpolluted rivers and from semi-artificial experimental aquatic ecosystems, to reinforce these criteria. Such studies are particularly necessary to establish the maximum concentrations associated with flourishing populations of resistant coarse fish species, and the modifying effects of other pollutants, especially zinc, in the water. The concentration of cadmium in muscle of fish exposed for long periods to low concentrations of cadmium in the water under either laboratory or field conditions is highly variable. The reasons for these differences are not clear. A bibliography of 82 references is appended.

2897. EIFAC Working Party on Water Quality Criteria for European Freshwater Fish with the cooperation of the United Nations Environment Programme (UNEP). 1978. Report on copper and freshwater fish. Water Research 12:277-280.

Copper's mode of action on aquatic organisms is not clear but toxicity is largely attributable to Cu^{2+}. The cupric form of copper, the species commonly found, is readily complexed by inorganic and organic substances and is adsorbed onto particulate matter. For this reason, the free ion rarely occurs except in pure acidic soft waters. Analytical techniques commonly used to distinguish between toxic ionic copper and non-toxic soluble copper complexes are not accurate at low concentrations, making interpretation of field data difficult; where possible, copper concentrations are expressed herein as "soluble copper", i.e., that which passes through a millipore filter of average porosity 0.45 u. Toxicity is increased by reduction in water hardness, temperature, dissolved oxygen, chelating agents such as EDTA and NTA, humic acids, amino acids, and suspended solids but little is known of the effect of pH. Acutely lethal concentrations of copper to European species of fish in hard water range over 1.5 orders of magnitude. No reliable comparative data are available for different species in soft water, for the young stages, or for sublethal effects. Significant adverse effects on growth of some species, including rainbow trout, occur at about 0.1 of the LC-50 (96 hr) value. Aquatic plants and algae and invertebrates are generally more resistant than fish and there is no evidence that fisheries in waters containing copper have been adversely affected because of a reduction in food organisms. The toxicity of copper in natural waters, except soft water free from organic matter and suspended solids, is less than that predicted from laboratory tests in clean water, probably because of the presence of non-toxic complexes and insoluble precipitates. Sewage effluents containing copper are also less toxic than would be predicted from laboratory data. The presence of non-toxic complexes may partly explain the existence of brown trout populations where the annual 50 and 95 percentile values of soluble copper were 0.17 and 0.38 of the LC-50 (48 hr) value to rainbow trout, and some non-salmonid species where the corresponding values were 0.17 and 0.66, respectively. Only tentative water quality criteria can be formulated at present because there are virtually no field observations that indicate unequivocally the concentrations of copper that are not inimical to fish populations or fisheries. Also, quantitative data on size and structure of fish populations are not available, and other poisons are frequently present with copper. Only meager qualitative data are available for non-salmonid species. In the absence of data on the precise effects of copper on natural fish populations, considerable reliance has to be placed on laboratory data. It is suggested that the maximum safe concentrations should be based on annual 50 and 95 percentile values of soluble copper of 0.05 and 0.2, repspectively, of the threshold LC-50 to rainbow trout, taking into account the effect of water hardness. A bibliography of 111 references is appended.

2898. Eversole, A.G. 1978. Marking clams with rubidium. Proc. Natl. Shellfish. Assn. 68:78. (Abstract).

Hard shelled clams, Mercenaria mercenaria, were successfully marked with rubidium by rearing seed clams in artificial seawater containing rubidium chloride. Clams exposed for 48 and 96 hrs to 10,000, 1000, 100, and 10 mg/l RbCl contained levels of Rb^+ significantly higher than controls. Siphon extension and survival of clams was not affected by RbCl at concentrations less than 10,000 mg/l. Also, significantly higher levels of Rb^+ were present in tissue for up to 3 wks after clams were exposed to 1000 mg/l RbCl for 96 hrs and transferred to uncontaminated water. Diatoms, Phaedactylus tricornutum, exposed for 24, 48, and 96 hrs to 10,000, 1000, and 100 mg/l RbCl had significantly higher levels of Rb^+ than controls. Clams cultured for 96 hrs in vessels containing diatoms exposed to 1000 mg/l RbCl had significantly more Rb^+ than clams grown with unlabelled diatoms. Clams exposed to 1000 mg RbCl/1 solutions with and without diatoms contained levels of Rb^+ significantly higher than clams reared only with labelled diatoms. No significant difference was detected between clams grown with and without diatoms at 1.0 g/l RbCl. Mud crabs, Panopeus herbstii, were offered Rb^+-labelled clams for 96 hrs then sacrificed or transferred to containers with unlabelled clams for 7 days. Control crabs were fed unlabelled clams and sacrificed at 96 hrs, and at 7 days. Fecal strands of experimental crabs had evelated levels of Rb^+ with peak values at approximately 132 hrs. Four tissues dissected from control and experimental crabs were analyzed. Highest levels of Rb^+ were found in hepatopancreas of experimental crabs after 96 hrs, with no apparent difference after 7 days.

2899. Fales, R.R. 1978. The influence of temperature and salinity on the toxicity of hexavalent chromium to the grass shrimp Palaemonetes pugio (Holthuis). Bull. Environ. Contamin. Toxicol. 20:447-450.

Chromium was more toxic to shrimp at higher temperatures and lower salinities. In 10 o/oo S water, the LC-50 (48 hr) values were 81 mg Cr/l at 10 C, 39 at 15 C, 37 at 20 C, and 21 at 25 C. In 20 o/oo S, LC-50 (48 hr) levels were 147, 107, 78, and 77 mg Cr/l at respective temperatures.

2900. Georgiadis, G. 1977. Die auswirkung verschiedener temperatur- und salinitatskombinationen auf Gammarus fossarum Kock, 1835. Crustaceana Suppl. 4:112-119. (In German, English summary).

Data are given on tolerance, preference, concentration of hemolymph, and oxygen consumption of Gammarus fossarum exposed to different combinations of NaCl (500 to 3000 mg/l) and temperature (6, 12, 20, 26 C). Observations on Gammarus pulex and G. roeselii are included for comparison.

2901. Hamdy, M.K. and S.R. Wheeler. 1978. Inhibition of bacterial growth by mercury and the effects of protective agents. Bull. Environ. Contamin. Toxicol. 20:378-386.

Mercury-sensitive clones of Bacteroides and Clostridium were isolated and utilized to ascertain effects of mercury in combination with tryptone, ground rubber, and various sediment types. Ground rubber and organic-SH clay sands protected bacterial cells, apparently by chemi-sorptive behavior.

2902. Hasnain, A.U., I. Kimura, K. Arai, and T. Yasui. 1978. Comparative studies on the tryptic digestion of actomyosins and myosins from several fish species - II. changes in Ca^{2+} and EDTA-ATPases. Bull. Japan. Soc. Sci. Fish. 44:143-147.

Ca^{2+}- and EDTA-ATPase of actomyosins from several fish species and rabbit were assayed during digestion with trypsin. During digestion, Ca^{2+}-ATPase of heat denatured samples of bigeye tuna and carp actomyosins showed patterns which were identical with those of their respective fresh preparations. A higher initial activation was a general feature of the tuna actomyosins if the assay of Ca^{2+}-ATPase was performed in 60 mM KCl. The initial activation of tilapia actomyosin Ca^{2+}-ATPase was of a lesser extent, and was absent from carp, yellowtail and flatfish actomyosins. At the higher KCl concentration (500 mM) in the ATPase assay, the response of Ca^{2+}-ATPase was altogether monophasic, i.e. devoid of any initial activation, even in the case of rabbit actomyosin. EDTA-ATPase pattern of actomyosin digestion by trypsin closely resembled the pattern of Ca^{2+}-ATPase at the higher KCl concentration. The activation of myosin Ca^{2+}-ATPase of tuna species occurred to a lesser extent than that of actomyosin ATPase, and the reversal of the order of stability observed in case of actomyosin ATPase of tilapia and skipjack tuna was no longer noted. The reasons for these discrepancies are discussed.

2903. Hodson, P.V., B.R. Blunt, and D.J. Spry. 1978. Chronic toxicity of water-borne and dietary lead to rainbow trout (Salmo gairdneri) in Lake Ontario water. Water Research 12:869-878.

Rainbow trout exposed to lead in Lake Ontario water demonstrated an LC-50 (21 day) value of 2400 ug Pb/l. At lead concentrations ranging from 3 to 120 ug/l, the log of Pb concentrations in most tissues of exposed fish appeared linearily related to the log of Pb concentrations in water. Highest concentrations in trout exposed to 100 ug Pb/l for 16 to 32 wks occurred in opercular bone at 100 mg/kg followed by gill and kidney at 15 mg/kg. Lead accumulation by brain was not clearly demonstrated. Exposure over 32 wks to Pb in water at concentrations as low as 13 ug/l caused significant increases in red blood cell (RBC) numbers, decreases in RBC volumes, decreases in RBC cellular iron content and decreases in RBC δ-amino levulinic acid dehydratase activity. No changes were observed in hematocrit or whole blood iron content. The changes indicated increased erythropoiesis to compensate for inhibition of hemoglobin production and increased mortality of mature red blood cells. After 32 wks exposure to 120 ug Pb/l, 30% of remaining fish exhibited black tails, an early indication of spinal deformities. Lead added to food was not available for Pb uptake by fish. Lead content of fish exposed to dietary lead was not elevated above control levels. The majority of lead consumed could be accounted for in feces. Dietary lead may have slightly inhibited the uptake of dietary iron.

2904. Hughes, M.R. 1976. The effects of salt water adaptation on the Australian black swan, Cygnus atratus (Latham). Comp. Biochem. Physiol. 55A:271-277.

Body weight, plasma and tear concentrations, hematocrit, tissue sizes and Na, K, and Cl excretion in salt gland secretion (SGS) and cloacal fluid (CF) were studied in freshwater (FW) and saltwater (SW) adapted Australian black swan, Cygnus atratus, cygnets and adults. FW cygnet plasma Na 119, K 48 m-equiv/l were significantly different from adult FW swan plasma of Na 142; K 1.0. Salt adaptation increased cygnet plasma Na, 136 and salt and Harderian gland sizes, but plasma K, hematocrit, tear ion concentration, heart, kidney and adrenal gland size were unaffected. Hematocrit and plasma Na, K, and Cl of adults swans were unaffected by saltwater adaptation. The Na and K content of spontaneously formed SGS of FW and SW adapted cygnets were the same. A SW cygnet stomach loaded with Na, 500; K, 25 m-equiv/l produced SGS at 0.35 ml/min/kg, an unusually high rate; adults secreted at about 1/3 this rate. FW adults eliminated ½ the imposed salt loads in SGS (Na, 548 m-equiv/l) and 1/5 in CF (Na, 137 m-equiv/l). SW swans secreted only 1/3 of the load extrarenally (Na, 656 m-equiv/l) while cloacal excretion (Na, 266 m-equiv/l) increased to ½ the load given. In FW adult swans the first CF sample was obtained 90 min after the salt loading and in SW adults 4 min after loading, suggesting the FW swans absorbed the salt loads more completely and produced more SGS, but that SW swans allowed the loading solution to pass through the gut to be excreted as CF.

2905. Huguenin, J.E. 1977. The reluctance of the oyster drill (Urosalpinx cinerea) to cross metallic copper. Proc. Natl. Shellfish. Assn. 67:80-84.

The predatory snail, U. cinerea, is extremely reluctant to cross metallic copper, and this is due to some characteristic of the metal rather than to effects of physical obstruction. It was also shown that the width of copper strip is an important parameter in preventing crossings. Copper barriers at least as wide as the largest animals are recommended for maximum effectiveness.

2906. Yamamoto, Y., T. Ishii, and S. Ikeda. 1978. Studies on copper metabolism in fishes - III. existence of metallothionein-like protein in carp hepatopancreas. Bull. Japan. Soc. Sci. Fish. 44:149-153. (In Japanese, English summary).

The appearance of copper-bound metallothionein in hepatopancreas of carp kept in an 0.1 mg/l copper solution for 2 weeks was determined. Hepatic soluble fractions from controls and copper-exposed fish showed that: copper as well as zinc was eluted in two fractions and most of the copper appeared in the second fraction (F-2) in controls; copper and free SH-group contents in F-2 from copper-exposed fish significantly increased when compared to controls; copper, zinc and free SH-groups were diminished in F-2 from copper-exposed fish; soluble fractions from control and copper-exposed fish on incubation in copper incorporated the additive copper into F-2 fractions at a level much higher in experimentals than controls. In addition, the zinc in F-2 was replaced by copper and the free SH-groups in this fraction disappeared. The molecular weight of F-2 was estimated to be about 10,000. These findings indicate that, in carp, hepatopancreas copper induces the synthesis of a copper-binding protein which can be identified as a metallothionein-like protein.

2907. Karapetian, J.V. and A.M. Shahmoradi. 1978. Arsenic concentration in canned tuna fish and sardine. Bull. Environ. Contamin. Toxicol. 20:602-605.

Canned tuna fish from the Persian Gulf and canned sardines from the Caspian Sea were analyzed for arsenic. Tuna contained a mean of 0.78 mg As/kg, ranging from 0.65 to 1.00; sardines contained 1.0 mg As/kg, ranging from 0.9 to 1.2.

2908. Kikuchi, T., H. Honda, M. Ishikawa, H. Yamanaka, and K. Amano. 1978. Excretion of mercury from fish. Bull. Japan. Soc. Sci. Fish. 44:217-222. (In Japanese, English summary).

The possibility of removing mercury from fish heavily contaminated by methylmercury was examined in two series of rearing experiments using two marine species of fish: conger eel (Astroconger myriaster) and sea bream (Chrysophrys major). In the first series, conger eel from Kagoshima Bay, with natural levels of mercury of 1.0 mg/kg wet wt in muscle, 0.67 mg/kg in spleen, and 1.8 mg/kg in liver, were kept in Hg-free seawater and fed raw fish flesh for 7 weeks. Mercury levels were reduced by 50% in 5 wks for muscle and spleen, and in 3 wks for liver. In the second series, sea bream were fed for 7 wks with pellets containing either methylmercury or mercuric chloride at a level of 1.0 mg/kg and subsequently fed with either commercial pellet feed or pellets impregnated by a mixture of cysteine, pectin, and chitosan for another 7 wks. Mercury concentrations at the end of the first feeding period were 0.9 mg/kg in kidney and 0.25-0.40 in muscle, liver, brain, and spleen. During the subsequent feeding period, the mercury level was reduced to less than 0.2 mg/kg in every tissue examined, with best results in the group fed pellets supplemented by the mixture mentioned. When fed pellets containing mercuric chloride, the mercury level in any tissue never reached 0.2 mg/kg, even after 7 weeks, and suggests that mercury in this chemical form will excrete readily.

2909. Koli, A.K. and W.T. Canty. 1978. Determination of methylmercury in fish of South Carolina. Bull. Environ. Contamin. Toxicol. 20:537-543.

It was concluded that mercury in muscle tissue from brown trout containing 1.75 mg total Hg/kg wet wt was in the form of mono- and dimethylmercury.

2910. Koli, A.K., S.S. Sandhu, W.T. Canty, K.L. Felix, R.J. Reed, and R. Whitmore. 1978. Trace metals in some fish species of South Carolina. Bull. Environ. Contamin. Toxicol. 20:328-331.

Six species of freshwater and marine fishes of South Carolina were collected and analyzed for Cu, Fe, Zn, Mn, Cd, and Hg. Values, in mg/kg whole body wet wt, ranged from 0.01 to 0.20 for Cu, 0.30 to 7.4 for Fe, 0.02 to 5.2 for Zn, 0.02 to 0.25 for Mn, <0.01 to 0.03 for Cd, and 0.12 to 0.63 for Hg. In general, marine fishes contained higher levels of all metals than freshwater species, and larger fish have higher residue levels than small fish of the same species.

2911. Kremling, K., J. Piuze, K. von Brockel, and C.S. Wong. 1978. Studies on the pathways and effects of cadmium in controlled ecosystem enclosures. Marine Biology 48:1-10.

Two experiments were conducted in which cadmium was added to seawater and its plankton, primarily Chaetoceros spp., enclosed in plastic containers moored in Saanich Inlet (Vancouver Island, Canada). In both experiments, two enclosures (ca. 68 m^3 each) were used. One was spiked with about 1.3 ug/l cadmium, while the other served as a control (0.075 ug/l) to assess the fate of the added metal and its effect on marine phytoplankton. In both experiments, the pattern of biological events was similar in the cadmium-treated bag and the control. Furthermore, there were no marked differences in phytoplankton species composition, indicating that, at this concentration, cadmium did not affect the ecosystem. The rate of removal of cadmium by biological processes was relatively slow. The fraction of metal accumulated (for 2 and 4 weeks, respectively) in the settling material was less than 1% for the cadmium-treated bags. Experiments on the mechanism of cadmium binding indicated that the major part of the particulate metal is loosely bound to outer cell membranes.

2912. Lasserre, P., G. Boeuf and Y. Harache. 1978. Osmotic adaptation of Oncorhnychus kisutch Walbaum. I. seasonal variations of gill Na^+-K^+ ATPase activity in coho salmon, 0^+-age and yearling, reared in fresh water. Aquaculture 14:365-382.

An eventual improvement in salmonid production in seawater will depend on a fundamental understanding of the natural osmotic behavior, which demands, in turn, seaward migration of young salmonids and development of osmoregulatory processes. Seasonal changes in gill Na^+-K^+ ATPase of coho salmon were studied on two successive broods, 0^+-age and yearling, of the same origin reared under natural conditions in a freshwater hatchery off the Brittany coast (France). Gill ATPase changes are of a rhythmical nature, showing that a seasonal activation of the branchial Na^+-K^+ ATPase affects one part of the population only. Both age groups, 0^+-age and yearlings, present two peaks of Na^+-K^+ ATPase activity during the year, in spring and in autumn, separated by a low activity period in summer and in winter. Peaks of ATPase activity in autumn (both groups) and spring (yearlings) correspond, roughly, with the equinox. However, the spring activity rise of 0^+-age fish starts later. Levels of gill ATPase activity are probably a function of fish size at a given season. Duration of Na^+-K^+ ATPase activation may be affected by high temperatures of late spring and thus may fluctuate from year to year. Yearly variations in branchial Mg^{2+} ATPase were evidenced in both groups; at present these variations are impossible to correlate with the smolting process. Spring and autumn rises in gill Na^+-K^+ ATPase of coho salmon in freshwater indicate changes in osmoregulatory physiology preparatory to seaward migration. Authors conclude that gill ATPase activity gives aquaculturists some indication of the migratory tendencies in young freshwater salmon and thus the euryhalinity possibilities of the species at a given time.

2913. Longstreth, D.J. and B.R. Strain. 1977. Effects of salinity and illumination on photosynthesis and water balance of _Spartina_ _alterniflora_ Loisel. Oecologia 31:191-199.

Salt marsh grass, _Spartina_ _alterniflora_, was collected from North Carolina and grown under controlled nutrient, temperature, and photoperiod conditions. Plants were grown at two different illumination levels under variable substrate salinities. Leaf photosynthesis, transpiration, total chlorophyll, leaf xylem pressure, and specific leaf weight were measured. Growth at low illumination and high salinity (30 o/oo) resulted in a 50% reduction in photosynthesis. The reduction in photosynthesis of plants grown at low illumination was correlated with an increase in gaseous resistance. Photosynthetic rates of plants grown at high salinity and high illumination were reduced only slightly compared to rates in plants grown in 10 o/oo. Both high salinity and high illumination were correlated with increases in specific leaf weight. Chlorophyll data indicate that specific leaf weight differences were the result of increases in leaf thickness. It is therefore hypothesized that photosynthetic response can be strongly influenced by salinity-induced changes in leaf structure. Similarities in photosynthetic rate on an area basis at high illumination were apparently the result of increases in leaf thickness at high salinity. Photosynthetic rates were generally high, even at salinities close to open ocean water. It is concluded that salinity rarely limits photosynthesis in _S._ _alterniflora_.

2914. Madrid, E., I.P. Zanders and F.C. Herrera. 1976. Changes in coelomic fluid and intracellular ionic composition in holothurians exposed to diverse sea water concentrations. Comp. Biochem. Physiol. 54A:167-174.

Ionic concentrations, including Na, K, Cl, Ca, and Mg, of coelomic fluid of Isostichopus badionotus equilibrated with 80 and 120% seawater in 4-6 hr. With increasing external medium concentration, intestinal albumin space remained constant whereas intracellular space decreased; in muscle, total water and intracellular space decreased and extracellular space increased. Non-albumin space ionic content per unit dry weight, with the exception of intestinal sodium, remains practically unchanged in intestine and muscle in passing from 80 to 120% seawater. Intracellular ionic concentrations rise proportionately to that of external medium. Adjustment of intracellular osmolality is due mainly to water movements into and out of the cells.

2915. Papadopoulou, C., G.D. Kanias, and E.M. Kassimati. 1978. Zinc content in otoliths of mackerel from the Aegean. Marine Poll. Bull. 9:106-108.

Zinc content in otoliths of the mackerel, Scomber japonicus colias, ranged from 7.2 mg/kg dry wt to 43.6 mg/kg dry wt. In general, zinc content decreased linearly with fish age and body length.

2916. Pentreath, R.J. and M.B. Lovett. 1978. Transuranic nuclides in plaice (Pleuronectes platessa) from the north-eastern Irish Sea. Marine Biology 48:19-26.

Concentrations of a number of alpha-emitting nuclides, Pu-238, Pu-239/240, Am-241, Cm-242, and Cm-243/244 were determined in organs of flatfish caught in the vicinity of a nuclear fuel reprocessing plant. Fish were taken for analysis every 3 months for 2 years. Highest concentrations of plutonium and americium nuclides were found in kidney, and lowest in muscle. In all organs analysed, concentrations of americium were greater than plutonium. Am values were also greater than plutonium when related to rates of discharge of these two elements, and gave higher concentration factors over samples of filtered shore-line seawater taken from the area.

2917. Robinson, K.R. 1977. Reduced external calcium or sodium stimulates calcium influx in Pelvetia eggs. Planta 136:153-158.

Effect of external Ca and Na ion concentrations on Ca fluxes in eggs of the marine brown alga Pelvetia fastigiata was measured. Decreasing external Ca^{2+} greatly increased permeability of eggs to Ca^{2+}; at 1.0 mM external Ca^{2+} this permeability was 60X greater than at the normal 10 mM Ca^{2+}. Lowering external Na^+ also increased Ca^{2+} influx; at 2 mM Na^+, the Ca^{2+} influx was 2-3X greater than normal Na^+ if choline was used as a Na^+ substitute. Lithium was less effective as a Na^+ substitute in increasing Ca^{2+} influx. The extra Ca^{2+} influx in low Na^+ seemed to be dependent on internal Na^+. Ca^{2+} efflux increased transiently and then declined in low Na^+ media.

2918. Sakamoto, S. and Y. Yone. 1978. Requirement of red sea bream for dietary iron - II. Bull. Japan. Soc. Sci. Fish. 44:223-225.

In order to determine amount of dietary iron required by the marine teleost Chrysophrys major, the effect of dietary iron on some biological and chemical characteristics of blood were examined using diets with different levels of iron over a 90-day feeding trial. Fish fed dietary iron levels lower than 150 mg Fe/kg diet showed lower values for mean corpuscular constants of blood and iron content and iron saturation index of blood serum, and higher values for total iron binding capacity and unsaturated iron binding capacity of blood serum than those found for fish receiving higher dietary iron levels. It is concluded that the dietary iron requirement of red sea bream is approximately 150 mg/kg.

2919. Sarkka, J., M.L. Hattula, J. Janatuinen, and J. Paasivirta. 1978. Chlorinated hydrocarbons and mercury in aquatic vascular plants of Lake Paijanne, Finland. Bull. Environ. Contamin. Toxicol. 20:361-368.

Mercury had been discharged into L. Paijanne until 1968 as slimicidal agents of a wood-processing industry. Between 1972-74, a total of 23 species of aquatic plants were analyzed for Hg and chlorinated hydrocarbons. Mercury, in ug/kg dry wt, for all species ranged from 8 to 122 with a mean of 54 ug/kg (standard deviation 51). Elodeids and Helophytes contained highest mean levels (62-65 ug/kg dry wt) and Nymphaeids the lowest (14 ug/kg).

2920. Sasayama, Y. and C. Oguro. 1976. Effects of ultimobranchialectomy on calcium and sodium concentrations of serum and coelomic fluid in bullfrog tadpoles under high calcium and high sodium environment. Comp. Biochem. Physiol. 55A:35-37.

The role of the ultimobranchial gland of bullfrog tadpoles on the regulation of Ca and Na levels in serum and coelomic fluid was studied. Calcium levels in serum and coelomic fluid in the ultimobranchialectomized tadpoles increased markedly after 48 hr treatment with high Ca and Na media, although no changes were found in these levels untreated in tap water. The tendency to hyponatremia was more pronounced in the ultimobranchialectomized tadpoles than in the sham-operated. It is concluded that one function of the ultimobranchial gland of anuran larva is to suppress acute rise of calcium levels in body fluid.

2921. Sastry, K.V. and P.K. Gupta. 1978. Effect of mercuric chloride on the digestive system of a teleost fish, Channa punctatus. Bull. Environ. Contamin. Toxicol. 20:353-360.

The LC-50 (96 hr) value of mercuric chloride was determined as 1.8 mg/l for C. punctatus. Various tissues from survivors were analyzed for activities of alkaline phosphatase, acid phosphatase, glucose-6-phosphatase, amylase, pepsin, trypsin, tripeptidase glycyl-glycine dipeptidase and carnosinase. The three phosphatases were inhibited in liver, but showed increased activities in pyloric caeca and intestine. Amylase, pepsin, and trypsin also exhibited a slight increase in activity. There was no significant alteration in peptidase activites. Authors conclude that mercury inhibits liver phosphatase activities, but not digestive enzymes.

2922. Somero, G.N., T.J. Chow, P.H. Yancey, and C.B. Snyder. 1977. Lead accumulation rates in tissues of the estuarine teleost fish, Gillichthys mirabilis: salinity and temperature effects. Arch. Environ. Contamin. Toxicol. 6:337-348.

Tissue-specific lead accumulation rates were determined in Gillichthys as a function of seawater lead concentration (50-2650 ug Pb/l), duration of exposure to lead acetate (up to 130 days), salinity (25%-100% seawater), and temperature (10 and 20 C). Distinct tissue-specific accumulation rates were found. Spleen, gill, fin, and intestine accumulated the greatest amounts of lead; liver and muscle the least. Maximum Pb values, in mg Pb/kg dry wt, of control fish were 11.6 for spleen, 11.8 for gill, 15.7 for fin, 6.6 for intestine, 2.9 for skin, 7.9 for vertebrae, 2.6 for liver and 1.9 for muscle. After exposure for 8 days to 265 ug Pb/l, maximum values recorded were 31.2 mg/kg dry wt for spleen, 28.8 for gill, 13.9 for intestine, 8.4 for skin, 18.0 for vertebrae, 3.4 for liver, 0.7 for muscle and 6.2 for brain. After 130 days in 265 ug Pb/l, maximum values recorded were 100-125 mg Pb/kg dry wt for spleen, fin, and gill. Exposure for 100 days to 50 ug Pb/l produced values in the 20-30 mg/kg dry wt range for spleen, intestine and gill; lower values were recorded for fin, skin, liver, vertebrae, and muscle in that order. A similar pattern was observed at 2650 ug Pb/l after 90 days, with maximum values recorded approaching 1000 mg Pb/kg dry wt in spleen. Decay of lead from tissues of lead-exposed fish was observed only for gill, fin, and intestine, tissues which all possess an outer or inner covering of mucus. It is suggested that the rapid turnover of lead in these mucus-covered tissues is a result of lead complexing with mucus and subsequent loss of lead when the mucus layer is sloughed off. In spleen and vertebrae, lead levels continued to rise in fish returned to natural (unspiked) seawater from lead-spiked seawater. The rate of lead accumulation was dependent on both salinity and the temperature. Fish held at high temperature accumulated lead more rapidly than fish held at low temperature. The rate of lead accumulation was inversely proportional to the salinity of the medium. Both of these environmental effects on lead accumulation rates could be significant in estuarine habitats where lead concentrations, salinity, and temperature vary seasonally.

2923. Somero, G.N., P.H. Yancey, T.J. Chow, and C.B. Snyder. 1977. Lead effects on tissue and whole organism respiration of the estuarine teleost fish, _Gillichthys mirabilis_. Arch. Environ. Contamin. Toxicol. _6_:349-354.

Oxygen consumption rates of whole fish and isolated gill tissue were measured in _Gillichthys_ exposed to lead-dosed seawater for varying periods of time. Whole organism oxygen consumption was significantly higher in fish exposed to media containing 2,650 ug Pb/l for up to 60 min at 20 C and 33 o/oo S than in those held for equivalent periods of time in non-leaded seawater. _In vitro_ gill respiration rates were virtually identical for control and lead-exposed fish (exposure to 265 ug Pb/l for up to 2 hrs at 25 C and 33 o/oo S). Lead-exposed fish were also extremely more active in the aquaria than controls. These findings suggest that lead-induced metabolic changes may derive more from lead effects on central nervous system coordination of activity and metabolism than from direct effects of lead on intermediary metabolism enzymes in each cell.

2924. Spehar, R.L., E.N. Leonard, and D.L. DeFoe. 1978. Chronic effects of cadmium and zinc mixtures on flagfish (*Jordanella floridae*). Trans. Amer. Fish. Soc. 107:354-360.

J. floridae, a freshwater cyprinodont, were exposed to cadmium and zinc as individual metals and as mixtures (4.3-8.5 ug Cd/l and 73.4-139.0 ug Zn/l) through one complete life cycle in Lake Superior water (45 mg/l total hardness). Cadmium and zinc did not act additively at sublethal concentrations when combined as mixtures; however, a joint action of the metals was indicated. Effects on survival showed that toxicity of Cd and Zn mixtures was little if any greater than toxicity of zinc alone. Mechanisms of zinc toxicity in this test were similar to those in previous chronic tests of individual metals, indicating that presence of cadmium did not influence mode of action of zinc. Comparisons between metal residues in fish exposed to each individual metal or to the metal mixtures showed that uptake of one metal was not influenced by the presence of the other.

2925. Thomson, A.J., J.R. Sargent, and J.M. Owen. 1977. Influence of acclimatization temperature and salinity on ($Na^+ + K^+$)-dependent adenosine triphosphatase and fatty acid composition in the gills of the eel, (*Anguilla anguilla*). Comp. Biochem. Physiol. 56B:223-228.

Microsomal Na/K-ATPase from gills of freshwater eels had an Arrhenius plot (log specific activity vs. temperature) discontinuity at 20 C. The corresponding enzyme from seawater eels had a discontinuity at 12 C. Fatty acids from total lipids of the gills of freshwater and seawater eels were rich in (n-6) and (n-3) fatty acids, respectively. Freshwater eels adapted to seawater for 3 months without a temperature change had an unchanged Arrhenius plot discontinuity and an unchanged fatty acid composition. The situation was unchanged after a further 3 months in seawater at low temperature. Seawater eels adapted to a higher temperature in seawater for 3 months yielded an Arrhenius plot discontinuity at 20 C and their gills fatty acid were now more saturated. These changes were reversed by re-adapting the eels for a further 3 months in seawater at a lower temperature. It is concluded that temperature and not salinity determines the degree of unsaturation of gill lipids. The position of discontinuity in the Arrhenius plot of a biomembrane enzyme can be correlated with the degree of unsaturation of membrane lipids under natural conditions, reflecting the fluidity of the biomembrane. The (n-3) and not the (n-6) polyunsaturated fatty acids yield fluid biomembranes at low temperatures.

2926. Tromballa, H.W. 1978. Influence of permeant acids and bases on net potassium uptake by Chlorella. Planta 138:243-248.

Salts of membrane-permeant acids and bases strongly influence net K uptake by Chlorella fusca. Na phenylacetate, acetate, isobutyrate, propionate, and butyrate added to buffered algal suspensions containing 0.1-0.2 mM KCl increasingly stimulated net K uptake. In contrast, K release was induced by the chlorides of imidazole, ammonia and methylamine. All these effects were found in the light and, less pronounced, in the dark. The dependence of net K movements on concentrations of salts added and on pH of medium suggests that free acids or bases are the effective agents. Between net uptake of K and uptake of labelled propionate a molar ratio close to 1 was found. It is concluded that internal pH of the cell is changed by the permeants. Acidification of the cytoplasm stimulates extrusion of protons coupled to uptake of K. Alcalization brings about proton uptake and K extrusion. Apparently, K/H exchange serves as a pH-stat of the cell.

2927. Tucker, C.S. and C.E. Boyd. 1977. Relationships between potassium permanganate treatment and water quality. Trans. Amer. Fish. Soc. 106:481-488.

Addition of 2, 4, and 8 mg/l $KMnO_4$ slightly decreased chemical oxygen demand of fish pond water. Treatment of samples with 4 and 8 mg/l $KMnO_4$ decreased biochemical oxygen demand but did not prevent depletion of dissolved oxygen within the 4-day test period. Addition of 4 and 8 mg/l $KMnO_4$ to water in plastic pools decreased phytoplankton abundance and gross photosynthesis and did not prove beneficial in increasing dissolved oxygen concentrations when oxygen concentrations were near 0 mg/l. Potassium permanganate was also highly toxic to bacteria in laboratory studies (LC-100 after 4 hrs = 4 mg/l). However, pond waters often contain large amounts of organic matter which express a $KMnO_4$ demand, rendering the chemical less effective as a bactericide. This implies that in treating bacterial fish diseases, enough $KMnO_4$ should be added to satisfy the $KMnO_4$ demand plus a bactericidal residual. The amount of $KMnO_4$ per application can be increased without harm to fish as toxicity to fish also decreased with increasing $KMnO_4$ demand. For example, the LC-100 (48 hr) values for $KMnO_4$ to bluegill sunfish, and fathead minnows decreased from about 5.0 mg/l in waters with a $KMnO_4$ demand of 0.1 mg/l to about 9.0 mg/l in waters with a $KMnO_4$ demand of 1.0 mg/l.

2928. Walker, R.L. and P.O. Fromm. 1976. Metabolism of iron by normal and iron deficient rainbow trout. Comp. Biochem. Physiol. 55A:311-318.

Iron metabolism in normal and iron deficient trout was studied after intraperitoneal injection of Fe-59. In both groups most of the Fe-59 was absorbed from the peritoneal cavity within 24 hr. Equilibrium between plasma Fe-59 pool and tissues was attained 8 days after injection. Liver iron, the main storage pool in trout, was reduced from the control level of 185 mg/kg wet wt to <100 mg/kg 16 days after bleeding whereas splenic iron stores were unaffected. In iron deficient fish the RBC Fe-59 content increased to 70-80% of the injected dose by day 16 compared to 50% in controls. This was attributed to the difference in reticulocyte count, which was 10-20% for bled fish and 2-3% in controls. Some iron accumulated by erythrocytes is temporarily stored as non-heme iron by these cells. An average of 15% of the injected Fe-59 was taken up by hepatic tissue of controls and remained there throughout the 30-day study. In iron deficient trout, liver radioiron was reduced from a high of 15% on day 2 to <1% of the initial dose by day 16 post bleeding. There was essentially no detectable loss of Fe-59 in the urine or feces of either normal control or iron deficient fish.

2929. Walter, A. and M.R. Hughes. 1978. Total body water volume and turnover rate in fresh water and sea water adapted glaucous-winged gulls, Larus glaucescens. Comp. Biochem. Physiol. 61A:233-237.

Total body water (TBW) volume and TBW turnover rate were measured by tritiated water disappearance rate in glaucous-winged gulls drinking either freshwater or seawater over 2 weeks. TBW volume was 79% BW and TBW turnover 0.064 ml/g/day in birds given freshwater; these values did not change when adapted to seawater. TBW volume is large in gulls compared to other species, but TBW turnover is similar to that of other birds.

2930. Wentsel, R., A. McIntosh, and G. Atchison. 1978. Evidence of resistance to metals in larvae of the midge Chironomus tentans in a metal contaminated lake. Bull. Environ. Contamin. Toxicol. 20:451-455.

Chironomid larvae removed from the west basin of Palestine Lake, Indiana, which received Cd, Cr, and Zn from electroplating plant wastes for at least 25 years, and chironomids from the relatively clean east basin were exposed to various lake sediments. In water for 96 hrs with contaminated sediments containing 1070 mg Cd/kg, 1680 mg Cr/kg, and 15,100 mg Zn/kg, only 48% of east basin chironomids survived while 75% of west basin insects survived. With uncontaminated sediments of 6.0 mg Cd/kg, 39.0 mg Cr/kg, and 184 mg Zn/kg, 76% of east basin and 33% of west basin populations survived 96 hrs. During exposure to heavily contaminated sediments, larval length increased 9% in east basin insects and 18% in west basin insects.

2931. Yamamoto, Y., T. Ishii, and S. Ikeda. 1977. Studies on copper metabolism in fishes - II. the site of copper accumulation in the tissues of carp. Bull. Japan. Soc. Sci. Fish. 43:1327-1332. (In Japanese, English summary).

Carp, Cyprinus carpio, were exposed to solutions containing 0.1 mg Cu/l for 2 weeks. Ceruloplasmin and direct-reacting copper contents in the serum of copper-exposed carp increased significantly compared to controls. By copper loading, a statistically apparent increase of copper content was observed in the hepatopancreas, gills, intestine and kidney. Hepatopancreas contained the highest copper content (28 mg/kg wet wt) with more than 70% of the copper in the supernatant fraction. Little, or no, copper was found in ultrafiltrate from the supernatant fraction. Analysis of the supernatant fraction demonstrated that most of the copper accumulated in hepatopancreas was bound to relatively low molecular weight proteins.

2932. Anderson, W.L. and K.E. Smith. 1977. Dynamics of mercury at coal-fired power plant and adjacent cooling lake. Environ. Sci. Technol. 11:75-80.

Mercury in coal, slag, fly ash, airborne particulate matter, soil, lake sediment, fish, macrophytes, and ducks, was determined at the Kincaid Power Plant-Lake Sangchris complex in central Illinois. Of 546 kg of mercury calculated to be in the 2.7 million metric tons of coal burned by the power plant from

September 1973 to August 1974, an estimated 97% was vaporized and emitted into the air. Mean concentrations of total mercury in soil were 0.022 mg/kg northeast of the power plant in the direction of prevailing winds, and 0.015 mg/kg to the southwest. Mean concentrations in lake sediment were 0.049 mg/kg in deposits that occurred after the power plant began operating in 1967, and 0.037 in earlier years. Seven species of fishes from Lake Sangchris (largemouth bass, black bullhead, green sunfish, bluegill, white crappie, white bass, channel catfish) contained low amounts of mercury. Mean Hg values for largemouth bass was 0.07 mg/kg wet wt compared to means of 0.16-0.56 for bass from three other Illinois lakes. Mean levels for other fish from Lake Sangchris ranged from 0.07 to 0.17 mg Hg/kg wet wt. Some, as yet, unidentified factor at Lake Sangchris has apparently suppressed mercury accumulation in the fishes. Total mercury concentrations, in mg/kg wet wt, in mallard, American wigeon, and blue-winged teal ducks ranged from 0.035 to 0.053 in breast muscle and 0.025 to 0.140 in liver; maximum individual level found was 0.37 in liver of a teal. Pondweed contained 0.04 mg Hg/kg dry wt in stems and 0.062 in leaves.

2933. Anon. 1975. Preliminary investigation of effects on the environment of boron, indium, nickel, selenium, tin, vanadium and their compounds. volume II. indium. U.S. Environ. Protect. Agen. Rept. EPA-560/2-75-005b. Avail. as PB-245 985 from Nat. Tech. Inform. Serv., U.S. Dept. of Comm., Springfield, VA 22151:38 pp.

Indium production in the United States is probably less than 20 metric tons per year. The American Conference of Governmental Hygienists recommend a Threshold Limiting Value of 0.1 mg/m^3 (air) based on experiments with mammals. Data involving humans are limited and as a result, possibly too much weight is given to a Russian report that individuals exposed to indium compounds during production complained of pains in joints and bones, tooth decay, nervous and gastrointestinal disorders, heart pains and general debility. This has not been reported in comparable U.S. activities. Since compounds of various radionuclides of indium are organ-specific, radioactive compounds of indium are used in diagnostic organ scanning. Toxicity of radioactive indium compounds is slight, only 3 of 770 patients exposed to indium showed effects. Stable indium and its compounds may cause local irritation on contact with the skin. Indium is poorly absorbed through intestine, with the result that oral levels of toxicity are quite high. Cells of the reticuloendothelial system phagocytize indium compound particles, with indium toxicity apparently due to concentration by these cells. Distribution of indium in the body can be controlled by the chemical form of indium, suspension medium, and mode of injection. Some indium salts apparently exert antitumor activity, but toxic side effects make treatment difficult. Effects of indium on lower animals, plants (cucumbers), and microorganisms (alga Chlorella vulgaris and bacterial strains of Azotobacter) are little known. Although there appears to be potential for occupational hazards to personnel in industries producing or utilizing indium, significant detrimental effects have not been reported in this country. A list of 79 references is appended.

2934. Anon. 1975. Preliminary investigation of effects on the environment of boron, indium, nickel, selenium, tin, vanadium and their compounds. vol. VI. vanadium. U.S. Environ. Protect. Agen. Rept. EPA-560/2-75-005f. Avail. as PB-245 989 from Nat. Tech. Inform. Serv., U.S. Dept. of Comm., Springfield, VA 22151:84 pp.

The United States is the largest world producer and consumer of vanadium. Release of vanadium to the environment from man's activities is estimated to exceed 30,000 metric tons per year; about two-thirds arises from combustion of residual fuel oil. In view of the solubility of vanadium oxide, much of the vanadium in wastes can be considered to enter the waters over a finite period of time. Natural sources of vanadium include wind erosion of rocks and transport from soils. Toxicity of vanadium and its compounds to humans varies from moderate to acute. There has been little apparent adverse effect of vanadium in the environment, but occupational hazards exist and are well-documented. The Threshold Limiting Value in air for concentration of vanadium compounds has been set: vanadium pentoxide dust, 1.5 mg/m^3; vanadium pentoxide fume, 0.1 mg/m^3; and ferrovanadium dust, 1.0 mg/m^3. Vanadium has marked effects on human metabolism, including a reduction in chloresterol, various enzymes, and sulfur-containing amino acids. Vanadium ingested by humans appears to be excreted largely unabsorbed. No evidence was found of teratogenicity, carcinogenicity or mutagenicity occasioned by vanadium. Some apparent allergic response was observed to develop after occupational exposures. Vanadium compounds may be absorbed through lungs, and, to a small extent, by intestine. Most orally ingested vanadium is excreted in the feces. Elevated urinary vanadium levels reflect vanadium exposure, and systemic vanadium is rapidly eliminated from the body by the kidneys. Vanadium interferes with sulfhydryl group metabolism and reduces hypercholesterolemia. Presumably, man and the higher animals do not accumulate vanadium in hazardous amounts. Toxicity in lower animals is greater than in humans and other mammals, and greatly dependent on exposure, mode of administration, and valence of vanadium ion. The order of V toxicity is $5^{+} > 3^{+} > 2^{+}$. The green blood pigment of tunicates, primitive marine chordates, contains vanadium and these organisms effectively accumulate V from seawater and silts. Some holothurians (sea cucumbers) also contain high levels of vanadium. Vanadium plays a role in the absorption and reduction of nitrogen by plants and possibly growth. Information on toxicity of plants to vanadium is relatively limited, particularly long-term effects. Plants accumulate and translocate vanadium, particularly at acidic pH. Phytotoxicity may involve interference with iron uptake by plants. Relatively little information is available concerning effects of vanadium on organisms, including algae, bacteria, molluscs, echinoderms, tunicates, and mammals. Since some of these species accumulate vanadium and some exhibit detrimental effects for acute exposure, potential environmental hazards from vanadium may exist if environmental vanadium levels increase. Eighty-four references are appended.

2935. Aoyama, I., Y.(oshinobu) Inoue, and Y.(oriteru) Inoue. 1978. Experimental study on the concentration process of trace element through a food chain from the viewpoint of nutrition ecology. Water Research 12:831-836.

Using Cs-137 in water as a tracer, authors evaluated predation of the freshwater teleost Astronotus ocellatus on top minnows, Oryzias latipes, as a function of feeding frequency, ration size per day, and weight change in Astronotus. Over a period of 120 days, the concentration of Cs-137 in Astronotus increased with ration size; the feeding interval had no effect on uptake of Cs-137; and the concentration in growing fish was suppressed, increasing in value with increase in weight.

2936. Badsha, K.S. and M. Sainsbury. 1978. Some aspects of the biology and heavy metal accumulation of the fish Liparis liparis in the Severn Estuary. Estuar. Coast. Marine Sci. 7:381-391.

Tissue levels of heavy metals, feeding habits, rates of growth, fecundity, and other aspects of general biology of L. liparis from the Severn estuary are reviewed. Concentrations, in mg/kg dry wt of whole fish minus guts, in L. liparis from Oldbury in September to March for 1973 through 1976 were 84 to 150 for zinc, 18 to 32 for lead, and 2.5 to 10.4 for cadmium. Lowest levels were generally in 1975-1976. Whole dried fish less guts from Berkeley in October to February for 1974 through 1976 contained 80 to 195 mg Zn/kg dry wt, 17 to 31 mg Pb/kg, and 3.1 to 7.1 Cd, with lowest values in 1975-76. At Hinkley Point, fish collected in September 1975 to March 1976 contained 94 to 160 mg Zn/kg dry wt, 12 to 18 Pb, and 2.4 to 4.4 Cd. In similarly sized fish from the same area, L. liparis contained higher levels of these metals, as much as 2X more, than a related species, five-bearded rocklings, Ciliata mustela.

2937. Bottino, N.R., R.D. Newman, E.R. Cox, R. Stockton, M. Hoban, R.A. Zingaro and K.J. Irgolic. 1978. The effects of arsenate and arsenite on the growth and morphology of the marine unicellular algae Tetraselmis chui (Chlorophyta) and Hymenomonas carterae (Chrysophyta). Jour. Exper. Marine Biol. Ecol. 33:153-168.

The effects of arsenic on marine phytoplanktonic algae varied with oxidation state of As, its concentration, and degree of illumination. Arsenate affected mainly algal growth but also morphology, whereas arsenite caused only morphological changes. When grown in modified seawater from the Gulf of Mexico, cell number of T. chui reached 0.04/l under the following time-arsenate concentration regimes: 2 days, 1.0 mg As/l; 5 days, 20 mg As/l; 8 days, 50 mg As/l. Differences in growth rates of H. carterae was not as pronounced. Studies on the incorporation of As-74 as arsenate into cells grown in artificial seawater indicated that arsenate was incorporated and later partially released by both T. chui and H. carterae. Both arsenate influx and efflux seemed to be energy-dependent phenomena since they varied with degree of illumination. Differences between rates of uptake and release of arsenic suggested that arsenate undergoes chemical changes after transport into algal cells.

2938. Brehm, P., and R. Eckert. 1978. Calcium entry leads to inactivation of calcium channel in Paramecium. Science 202:1203-1206.

Under depolarizing voltage clamp of Paramecium an inward calcium current developed and subsequently relaxed within 10 milliseconds. The relaxation was substantially slowed when most of the extracellular calcium was replaced by either strontium or barium. The relaxation is not accounted for by a drop in electromotive force acting on calcium, or by activation of a delayed potassium current. Relaxation of the current must, therefore, result from an inactivation of the calcium channel. This inactivation persisted after a pulse, as manifested by a reduced calcium current during subsequent depolarization. Inactivation was retarded by procedures that reduce net entry of calcium, and was independent of membrane potential. The calcium channel undergoes inactivation as a consequence of calcium entry during depolarization. In this respect, inactivation of the calcium channel departs qualitatively from the behavior described in the Hodgkin-Huxley model of the sodium channel.

2939. Buzinova, N.S. 1978. Dynamics of activity of digestive enzymes in fish under the influence of pollutants. Jour. Ichthyology 17:805-808.

Toxicity of an organic tin compound, triethyl stannic chloride (TESC), was determined on digestive enzymes of yearling mirror carp, Cyprinus carpio. Over a period of 60 days, amylase activity in gut decreased in 0.003 mg TESC/l administered via both water and food but not by water alone. Hepatopancreas amylase decreased in 0.003 mg/l from water but not water and food. Amylase activity of gut and hepatopancreas decreased in 0.1 mg TESC/l from water and from water, and food by 60 days and in 0.5 mg/l by 5 days. Activity of gut and hepatopancreas trypins declined in 30 days in 0.003 mg TESC/l when given via water and food, but not significantly when from water alone.

2940. Charbonneau, S.M., K. Spencer, F. Bryce, and E. Sandi. 1978. Arsenic excretion by monkeys dosed with arsenic-containing fish or with inorganic arsenic. Bull. Environ. Contamin. Toxicol. 20:470-477.

Four female Cynomologus monkeys were fed a single dose of fish homogenate of grey sole, Glypocephalus cynoglossus, which contained 77 mg As/kg. The homogenate dose was administered at approximately 1.0 mg fish-As/kg monkey body wt. Monkey chow food and drinking water contained 0.1 mg/kg and 0.01 mg/l total arsenic respectively. Sixty-seven percent of the arsenic was excreted with the urine and 10% with the feces within 5 days. The monkeys were later administered inorganic arsenic; 76% was excreted with urine and practically none with feces over 14 days.

2941. Clark, D.L., A.A. Weiss, and S. Silver. 1977. Mercury and organomercurial resistances determined by plasmids in Pseudomonas. Jour. Bacteriology 132:186-196.

Mercury and organomercurial resistance determined by genes on ten Pseudomonas aeruginosa plasmids and one Pseudomonas putida plasmid have been studied with regard to the range of substrates and the range of inducers. The plasmidless strains were sensitive to growth inhibition by Hg^{2+} and did not volatilize Hg^0 from Hg^{2+}. A strain with plasmid RP1 (which does not confer resistance to Hg^{2+}) similarly did not volatilize mercury. All 10 plasmids determine mercury resistance by way of an inducible enzyme system. Hg^{2+} was reduced to Hg^0, which is insoluble in water and rapidly volatilizes from the growth medium. Other plasmids in P. aeruginosa and P. putida conferred resistance to, and the ability to volatilize mercury from Hg^{2+}, but strains with these plasmids were sensitive to and could not volatilize mercury from the organomercurials methylmercury, ethylmercury, phenylmercury, and thimerosal. These plasmids, in addition, conferred resistance to the organomercurials merbromin, p-hydroxymercuribenzoate, and fluorescein mercuric acetate by a mechanism not involving degradation. In all cases, organomercurial decomposition and mercury volatilization were induced by exposure to Hg^{2+} or organomercurials. The plasmids differed in the relative efficacy of inducers. Hg^{2+} resistance with strains that are organomercurial sensitive appeared to be induced preferentially by Hg^{2+} and only poorly by organomercurials to which the cells are sensitive. However, the organomercurials p-hydroxymercuribenzoate, merbromin, and fluorescein mercuric acetate were strong inducers but not substrates for the Hg^{2+} volatilization system. With strains resistant to phenylmercury and thimerosal, these organomercurials were both inducers and substrates.

2942. Crowther, R.A. and H.B.N. Hynes. 1977. The effect of road deicing salt on the drift of stream benthos. Environ. Pollution 14:113-126.

The three major ions in common road salts (Cl^-, Na^+, Ca^{2+}) were monitored in Laurel Creek from December 1973 to February 1975 to determine whether levels of salt from road runoff affect the drift of benthic invertebrates of urban streams in southern Ontario. Maximum salt concentrations occurred during the winter, with highest levels being 1770 mg Cl^-/l, 9550 mg Na^+/l, and 4890 mg Ca^{2+}/l. Since most of the salt was entering the creek as NaCl, this chemical was used to test the drift response of two insects, *Hydropsyche betteni* and *Cheumatopsyche analis*, and one amphipod, *Gammarus pseudolimnaeus*. Pulses of salt to 800 mg Cl^-/l had no effect on drift patterns. Several experiments were conducted in Lutteral Creek which had been longitudinally divided. As much as 750 mg Cl^-/l produced no differences in drift between salted and unsalted channels. However, a pulse of 2165 mg Cl^-/l increased drift of all organisms in the salted channel; this became apparent only when the concentration exceeded about 1000 mg/l.

2943. Cutshall, N.H., J.R. Naidu, and W.G. Pearcy. 1978. Mercury concentrations in Pacific hake, *Merluccius productus* (Ayres), as a function of length and latitude. Science 200:1489-1491.

Mercury concentrations in hake increased with fish size and with the latitude of collection. Mercury levels in hake about 300 mm in length were <0.1 to 0.2 mg/kg wet wt, while concentrations in fish 600 mm in length were 0.4 to 0.5 mg/kg. Mean Hg concentrations rose from 0.085 mg/kg wet wt at 32°51'N latitude to 0.383 mg/kg at 48°00'-48°28'N. While the mercury-size trend is consistent with data for other species, the latitudinal trend is opposite to that reported for other fishes over the same geographical area. Authors conclude that latitudinal trends of mercury concentrations in fishes do not necessarily indicate trends of mercury concentrations in water. Instead, food habits and metabolism may cause the observed variations.

2944. Davenport, J. and A. Manley. 1978. The detection of heightened sea-water copper concentrations by the mussel *Mytilus edulis*. Jour. Marine Biol. Assn. U.K. 58:843-850.

An acute toxicity threshold of 0.09-0.10 mg/l added copper was determined for mussels from the Menai Strait which were exposed to $CuSO_4$ in a flowing seawater system. Median lethal times (50% mortality) was 255 hrs in 0.09 mg Cu/l, 242 hrs in 0.10 mg Cu/l, and 169 hrs in 0.18 mg Cu/l; MLT was not reached in 0.07 mg Cu/l by 12 days. The closure response of the mussel to added copper was shown to be a three-part process. First, a sharp adduction of shell valves is seen at a mean total copper concentration of only 0.021 mg/l. Then as the concentration rises, "testing" behavior is observed. Finally, shell valves close to isolate the mussel from its environment. The complete valve closure mechanism operates at copper concentrations of 0.2 mg/l or more. The initial valve adduction reaction occurred at a significantly higher mean total copper concentration of 0.16 mg/l in mussels which had been acclimated to 0.02 mg Cu/l for 10 days.

2945. Dorgelo, J. 1977. Comparative ecophysiology of gammarids (Crustacea:Amphipoda) from marine, brackish- and fresh-water habitats exposed to the influence of salinity-temperature combinations. IV. blood sodium regulation. Netherlands Jour. Sea Res. 11:184-199.

Blood sodium regulation as a function of salinity (0 to 45% SW) and temperature (5, 15, and 25 C) was determined for gammarids from marine littoral (*Chaetogammarus marinus*), oligohaline (*Gammarus tigrinus*) and freshwater (*G. fossarum*) environments. All three species were hyperosmotic over the salinity range at each temperature, except *G. fossarum* in supranormal, potentially lethal salinities. Gammarids showed hyperregulation at homoiosmotic levels that decreased from coastal to brackish water to freshwater origin. Generally, new steady state levels of blood sodium were reached within 48 hrs; Na alterations were rapid during the first hours. When placed in extreme salinities at 25 C, all animals died within 2 days. Temperature had no influence on regulation level of the 3 species. *G. tigrinus* resembled *C. marinus* in osmotic regulation more than *G. fossarum*, which may be linked to great salt tolerance. Small male *C. marinus*, averaging 9.2 mg dry wt, had higher blood Na content at 457 mM than large males of 27.5 mg at 431 mM Na; no differences were noted in other species.

2946. Ernst, W.H.O. and M. Marquenie-van der Werff. 1978. Aquatic angiosperms as indicators of copper contamination. Arch. Hydrobiol. 83:356-366.

Effluents of pig bioindustries cause copper contamination of water, mud and aquatic plants in ditches in the Netherlands. Aquatic angiosperms and algae, *Elodea nuttallii*, *Spirodela polyrhiza*, *Ceratophyllum demersum*, *Nuphar luteum*, *Vaucheria* sp., and *Oedogonium* sp., accumulate Cu to 33 to 4390 mg/kg dry wt at the effluent source and 5.1 to 42.0 mg/kg one km from the outfall. Plants from a control ditch contained 4.4 to 17.8 mg Cu/kg dry wt. Copper uptake by leaves of *Elodea* is active and can be described by a multiphasic system. Uptake depends on Cu concentration in the medium, temperature, pH, time, and ratio of biomass and water volume. Median lethal times in 6.4 mg Cu/l range from 2 to 3 wks for Elodea and Lemna minor, and to >4 wks for Callitriche platycarpa. This difference in copper resistance is discussed in relation to uptake and cellular localization of copper. The possibilities for transplant of hydrophtyes for biological monitoring are discussed in view of chemical analysis of water and mud.

2947. Findley, A.M., B.W. Belisle, and W.B. Stickle. 1978. Effects of salinity fluctuations on the respiration rate of the southern oyster drill Thais haemastoma and the blue crab Callinectes sapidus. Marine Biology 49:59-67.

Respiration rates of Thais and Callinectes were determined as a function of salinity at 20 C in animals acclimated to 10, 20, and 30 o/oo S. Effects of 10-5-10 o/oo, 20-10-20 o/oo, 30-10-30 o/oo S, and 10-30-10 o/oo S semidiurnal cycles (12 hr) of fluctuating salinity on respiration of the oyster drill and effects of diurnal (24.8 hr) salinity cycles on oyster drills and blue crabs were also studied. Respiration rate of 30 o/oo S acclimated oyster drills (679 ul O_2/g dry wt/hr) was significantly higher than individuals acclimated to 10 o/oo S (534 ul). Blue crab respiration was 170 ul O_2/g dry wt/hr at 30 o/oo S, but was significantly higher at 10 and 20 o/oo S. With the exception of the 20-10-20 o/oo S semidiurnal cycle, respiration rate of oyster drills declined as salinity fluctuated in either direction from the acclimation salinity and increased as salinity returned to the acclimation salinity. Semidiurnal salinity cycles produced greater changes in respiration rate of snails than analogous diurnal cycles. A 10-30-10 o/oo S pattern of fluctuation caused a greater percentage reduction in steady state respiration rate of drills than the 30-10-30 o/oo S pattern. Respiration rate of crabs varied slightly and inversely with fluctuating salinity. Crab respiration dropped during the initial phase of declining salinity at a rate directly proportional to rate of salinity decrease, perhaps representing a metabolic adjustment period by the crabs. The respiratory response of T. haemastoma to salinity is consistent with its incomplete volume regulation, while the response of C. sapidus is compatible with its ability to regulate extracellular fluid and osmotic and ionic composition.

2948. Fraser, J., D.T. Parkin and E. Verspoor. 1978. Tolerance to lead in the freshwater isopod Asellus aquaticus. Water Research 12:637-641.

Isopods from 3 sites in the River Trent basin were subjected to different amounts of lead pollution. Differential survival was recorded between size classes and sites that could be explained in terms of genetic adaptation. Mean lead levels in river water at Lea Marston were 0.05 to 0.06 mg/l between 1973 and 1975; levels at Rochester and Great Haywood were 0.03 mg Pb/l during this period. Of 40 isopods from Lea Marston held in 1500 mg Pb/l, as lead nitrate, for 24 hrs, 4 animals $<$ 4.0 mm length and 8 $>$ 4.0 mm survived. None and 1 small isopod, and 4 and 2 large isopods from Rochester and Great Haywood, respectively, survived in 1500 mg Pb/l. Survival differences in small specimens from the 3 sites were seen in concentrations as low as 500 mg Pb/l; size differences were apparent in a minimum of 250 mg Pb/l in isopods from all locations. Significance of the results is discussed in terms of adaptation to environmental pollution.

2949. Fuhrman, J.A., S.W. Chisholm, and R.R.L. Guillard. 1978. Marine alga Platymonas sp. accumulates silicon without apparent requirement. Nature 272:244-246.

Intracellular concentrations of total $Si(OH)_4$ acid in Platymonas could be as high as 500 mM with more than 100 mM $Si(OH)_4$ in the dissolved fraction. Despite this significant accumulation, authors were unable to demonstrate a silicon requirement in this alga. Because natural waters are often low in $Si(OH)_4$ relative to the requirements of diatoms, uptake of this element by organisms such as Platymonas sp. could represent a mechanism by which they limit the growth of other species without affecting themselves, a relationship known as amensalism.

2950. Fujiki, M(otto), M. Fujiki, S. Yamaguchi, R. Hirota, S. Tajima, N. Shimojo, and K. Sano. 1978. Accumulation of methyl mercury in red sea bream (Chrysophrys major) via the food chain. In: Peterson, S.A. and K.K. Randolph (eds.). Management of bottom sediments containing toxic substances. Proc. 3rd U.S.-Japan Experts' Meeting, November 1977, Easton, Maryland. U.S. Environ. Prot. Agen. Rept. 600/3-78-084:87-94.

Accumulation of methylmercury in the marine teleost, C.

major, can result from food chain accumulations—from diatoms, Skeletonema costatum, to copepods, Acartia clausi, or brine shrimp, Artemia salina, to the juvenile bream. Diatoms, reared for 24 hrs in seawater containing 5.0 ug/l methylmercury, accumulated 3.45 mg/kg. The diatoms containing methylmercury were fed to copepods for 4 days, at which time the concentration of methylmercury in Acartia reached 3.14 mg/kg. Copepods were then fed to juvenile red sea bream for 10 days. Methylmercury level in fish was 3.10 mg/kg after feeding. The concentration of methylmercury in diatoms and copepods was about 2000X that of culture solution. The increase of metal from food to fish was about 2X. However, the amount of methylmercury accumulated by the juvenile bream was about 120X that of controls.

2951. Fujiki, M., R. Hirota, and S. Yamaguchi. 1977. The mechanism of methylmercury accumulation in fish. In: Management of bottom sediments containing toxic substances. Proc. 2nd U.S.-Japan Experts' Meeting, October 1976, Tokoyo, Japan. U.S. Environ. Prot. Agen. Rept. 600/3-77-083:89-95.

The factors contributing to methylmercury accumulation in red sea bream, Chrysophrys major, were investigated by using seawater containing 0.5 ug/l methylmercury, bottom sediment from Minamata Bay, Japan, methylmercury of 0.015 mg/kg dry wt, total mercury of 192 mg/kg dry wt, and prawns, Penaeus japonicus, bait containing 0.133 mg/kg methylmercury. Fish placed in contaminated seawater accumulated methylmercury from 0.012 mg/kg wet wt to 0.033 in muscle tissue over 10 days. Fish fed methylmercury-contaminated prawns accumulated methylmercury in muscle increased from 0.012 to 0.020 mg/kg. Mercury levels were elevated within 2 days in fish in contaminated water and sediment. Fish raised in a tank containing sediment from Minamata Bay did not show an effective accumulation of methylmercury. During 10 days exposure, fish weight was higher in all three contaminated conditions than controls; there was no difference in length.

2952. Gadd, G.M. and A.J. Griffiths. 1978. Microorganisms and heavy metal toxicity. Microbial Ecology 4:303-317.

The environmental and microbiological factors that can influence toxicity of Ag, Cd, Co, Cu, Fe, Hg, Mg, Mn, Tl, and Zn are discussed with a view to understanding the mechanisms of microbial metal tolerance. Metal toxicity can be heavily influenced by environmental conditions: binding of metals to organic materials, precipitation due to alkaline pH, complexation, and ionic interactions with other metals. Organisms including bacteria, yeast, fungi, algae, and protozoans possess a range of tolerance mechanisms, most featuring some kind of detoxification. These include H_2S and organic compound production to form organometallic compounds or sulfides, transformation of metal valences, and intercellular detoxification after uptake and accumulation of metals. Some strains have a genetically-determined metal resistance. Many detoxification mechanisms occur widely in the microbial world and are not only specific to microbes growing in metal-contaminated environments. A bibliography of 120 references is appended.

2953. Gardner, D. 1978. Mercury in fish and waters of the Irish Sea and other United Kingdom fishing grounds. Nature 272:49-51.

Mean mercury concentrations in surface waters from various UK fishing grounds ranged from 16.6 ng/l to 57.8 ng/l (range for all stations was 0.0 to 443.0 ng/l). Mean mercury concentrations in fish flesh ranged from 0.10 to 0.64 mg/kg wet wt. Concentration factors of Hg from water to fish in different areas ranged from 2900 in unpolluted distant fishing grounds to 10,600 within Liverpool and Morecambe Bay. A concentration factor of 20,500 was obtained from water to fish in the central Irish Sea and around the Isle of Man; this anomaly is probably attributable to low Hg levels found throughout the year in this area, to current patterns, and to migratory habits of fish stocks.

2954. Glooschenko, W.A. and J.A. Capobianco. 1978. Metal content of _Sphagnum_ mosses from two northern Canadian bog ecosystems. Water, Air, Soil Poll. 10:215-220.

Samples of 6 species of _Sphagnum_ moss collected from Kinoje Lake, northern Ontario, and Porter Lake, Northwest Territories, Canada, were analyzed for 10 elements. On a dry weight basis, Ca was highest in concentration followed by Mg, Fe and Mn; other elements were lower by an order of magnitude or greater. Average metal concentrations, in mg/kg dry wt, in moss from Kinoje and Porter Lakes, respectively, were 1860 and 2220 for Ca, 530 and 1440 for Mg, 270 and 1020 for Fe, 290 and 270 for Mn, 61 and 83 for Hg, 37 and 35 for Zn, 23 and 7.0 for Pb, 14 and 13 for Cu, 3.5 and 2.8 for Cr, and 1.0 and 0.3 for Cd. The two Canadian sites were similar in elemental composition except that the Ontario site was higher in Cd and Pb, while the N.W.T. site was higher in Mg and Hg. These differences could be due to a combination of regional geochemical and human activity differences.

2955. Glover, H. 1977. Effects of iron deficiency on *Isochrysis galbana* (Chrysophyceae) and *Phaeodactylum tricornutum* (Bacillariophyceae). Jour. Phycol. 13:208-212.

Cultures of marine algae were grown in iron-limited chemostats containing between 0.5 and 15.9 ug atoms Fe/l. With increasing iron deficiency, photosynthetic rate per cell and assimilation number decreased. The pattern of photosynthesis was also altered. In Fe deficient cells the proportion of C-14 fixed in glycine and serine decreased with an accompanying increase into alanine after 3 min assimilation. Although there was no significant effect of Fe deficiency on the proportion of C-14 incorporated into total amino acids and amides, the percentage of total C-14 fixed in protein increased with increasing Fe deficiency. Cellular levels of chlorophyll a, carotenoids, cytochromes and protein also decreased with increasing Fe deficiency. However, the reduction in chlorophyll a/cell was not as great as that of cytochrome f_1, with the result that Fe deficient cells showed a marked increase in the ratio of chlorophyll a to cytochrome f_1.

2956. Gogate, S.S., S.M. Shah, and C.K. Unni. 1975. Strontium, calcium and magnesium contents of some marine algae from the west coast of India. Jour. Marine Biol. Assn. India 17:28-33.

Algae collected from the west coast of India in 1964 and 1965 were analyzed for strontium, calcium, and magnesium. Mean concentrations, in mg/kg dry wt, ranged from 19 to 646, with a high of 1460, for Sr; 1860 to 25,000 for Ca; and 2950 to 74,500, with a high of 118,400, for Mg. Strontium to calcium ratio in 2 species of brown algae varied between 0.022 and 0.030. In 4 species of green algae and 4 species of red algae Sr:Ca was 0.005 to 0.009 and 0.005 to 0.006, respectively. Brown algae accumulated Sr in preference to Ca from seawater.

2957. Greig, R.A. and D.R. Wenzloff. 1978. Metal accumulation and depuration by the American oyster, *Crasssostrea* virginica. Bull. Environ. Contamin. Toxicol. 20:499-504.

Oysters from Beaufort, North Carolina, were held under various conditions in natural seawater from Milford Harbor, Connecticut. Natural Beaufort populations contained <0.16 mg Ag/kg wet wt, <0.28 for Cd, 8.4 for Cu, and 515 for Zn. After 11 days, oysters contained <0.15 to 0.36 mg Ag/kg wet wt, 0.43 to 0.66 mg Cd/kg, 10.7 to 29.3 mg Cu/kg, and 281 to 563 mg Zn/kg; metal concentrations after 22 days were 0.49 to 1.00 Ag, 1.0 to 1.5 Cd, 18.4 to 41.6 Cu, and 346 to 410 Zn. Lowest Ag, Cd, and Cu levels were found in tanks with muddy sediments; these sediments contained <2.5 mg Cd/kg dry wt, 180 Cu, and 108 Zn. Maximum metal levels in oysters were from tanks with unfiltered seawater. Oysters transferred to Milford Harbor water for 42-48 weeks did not depurate metals. Cu decreased in unfiltered water and Ag decreased in filtered water, but most metals stayed constant or increased. Only Cu at week 27 was significantly lowered in oysters transferred to uncontaminated water at Beaufort, N.C., for 40 weeks, indicating that specimens retained their metal content even when in relatively unpolluted water.

2958. Gupta, A.B. and A. Arora. 1978. Morphology and physiology of Lyngbya nigra with reference to copper toxicity. Physiol. Plant. 44:215-220.

Effect of copper sulphate exposure for up to 8 days on morphology and physiology of the alga, L. nigra, was studied. Growth was inhibited in all treatments of 0.1 to 20.0 mg/l copper sulphate. There were no apparent morphological changes to 0.2 mg/l or during the first two days of treatment in higher concentrations of copper sulphate. In concentrations >0.2 mg/l, the first symptom of toxicity was the formation of many separation discs. Trichomes contracted longitudinally and cells became swollen and constricted at the cross walls. Cells also became yellowish due to loss of photosynthetic pigments. In 2.0 mg/l and above, vacuoles appeared in large numbers, indicating the moribund state of cells. Copper sulphate increased respiration at 0.5 mg/l, with greatest effect observed in 2.0 mg/l after 96 hrs. Inhibition of photosynthesis was detectable in 0.2 mg/l, and 100% inhibition took place in 2.0 mg/l after 96 hrs. In higher concentrations a conspicuous inhibition of photosynthesis was observed within 10 min. Copper content of the alga increased with increased concentration of copper sulphate while potassium content decreased over 192 hrs. Copper concentration rose from 8.0 to 12.7 mg/kg dry wt and K declined from 19.7 to 17.4 mg/kg dry wt as

$CuSO_4$ exposure increased to 20.0 mg/l from controls. Greatest comparative increase of Cu absorption from water was in 0.5 and 1.0 mg/l. Authors concluded that changes in physiological activity of the alga under treatment were closely linked with marked changes in morphology.

2959. Hamada, M., Y. Inamasu, and T. Ueda. 1977. On mercury and selenium in tuna fish tissues - III. mercury distribution in yellowfin tuna. Jour. Shimonoseki Univ. Fisheries 25:213-220. (In Japanese, English abstract and table subtitles).

Distribution of mercury in various tissues of Thunnus albacares was investigated. Mean concentrations of total mercury in muscle from all parts of tuna ranged from 0.14 to 0.37 mg/kg wet wt and methylmercury ranged from 0.13 to 0.34 mg/kg. Total mercury concentration was low in fins, scales, vertebrae, and cartilage; maximum level in these tissues was 0.04 mg Hg/kg. Tissues containing $\geq$0.10 mg/kg total Hg in some samples included gills, heart, liver, spleen (with a maximum of 2.1 mg Hg/kg), kidney, stomach, intestine, pyloric caeca, sinew, skin, and intestinal content of sardine, shrimp and squid. The ratio of methylmercury to total Hg in muscle was nearly 1:1.

2960. Helmy, M.M., A.E. Lemke, P.G. Jacob, and B.L. Oostdam. 1978. Effects of some trace elements on the blood of Kuwait mullets, Liza macrolepis (Smith). Jour. Exp. Marine Biol. Ecol. 34:151-161.

Hemopathological changes attributed to heavy metal poisoning were observed in blood smears of L. macrolepis taken after exposures of 96 hrs to graded doses, in mg/l, of copper (0.11-1.80), lead (1.15-18.36), or mercury (0.04-0.59) in a flow-through marine bioassay system. In general, changes in leucocytic profile, of increasing eosinophil but not lymphocyte percentage, appeared to be correlated with pathological changes caused by increasing copper and mercury concentrations. In contrast, blood samples of fish exposed to lead showed significant polychromasia and anisocytosis regardless of concentrations. Red blood cell count, hemoglobin content, and hematocrit were less valuable in diagnosis of copper and mercury effects. LC-50 (96 hr) values, in mg/l, were 1.43 for Cu, 14.61 for Pb, and 0.38 for Hg. The manifestations of poisoning by trace elements resemble pathological changes shown clinically and experimentally in mammals. Consequently, blood measurements on marine organisms may be diagnostic of undesirably high levels of copper and mercury and may constitute useful indicators of marine pollution.

2961. Hetherington, J.A., D.F. Jefferies, N.T. Mitchell, R.J. Pentreath, and D.S. Woodhead. 1976. Environmental and public health consequences of the controlled disposal of transuranic elements to the marine environment. *In*: Transuranium nuclides in the environment. Int. Atom. Energy Agen., Vienna. IAEA-SM-199/11:139-154.

Experience from the controlled disposal of liquid radioactive wastes from the nuclear power program of the United Kingdom has shown that the only releases of transuranic elements of potential environmental significance occur following fuel reprocessing. In this context, plutonium, because of its long half-life and high radiotoxicity, and the next most important transuranic, americium, have been studied. Radiological significance of these radionuclides following discharge to the marine environment, in terms of both dose to man and to environmental resources is reviewed. Both plutonium and americium are found in each of the three compartments: water, seabed sediment, and biota. The highest concentrations were found in particularly fine mud in estuaries close the the Windscale outfall. Radionuclide concentrations, in pCi/g wet wt, in 1974, were 10 for Pu-238,239,240 and 5.0 for Am-241 in sediment, 1.0 and 1.0 in seaweed *Porphyra*, and 0.004 and 0.003 in fish muscle; seawater contained 0.0002 pCi Pu/ml. Levels decreased in deeper sediment and in biota further from the sources. Tissue levels in the flatfish, *Pleuronectes platessa*, ranged from 0.0004 pCi Pu-239,240/g wet wt in muscle to 0.088 in kidney, and from 0.002 pCi Am-241/g in muscle to 0.59 in liver. In crabs, *Cancer pagurus*, concentrations ranged from 0.1 in muscle to 2.8 in gill for Pu and from 0.6 in muscle to 7.9 in gill for Am. In mussels, *Mytilus edulis*, levels were 1.6 for Pu and 3.9 for Am in visceral mass. The public health significance of those biota which represent potential human exposure pathways was evaluated and estimates of the dose rate to critical groups from current discharges were made. In parallel studies, attention was focused on exposure of fish and shellfish stocks. Dose rates were estimated by use of environmental data on contamination levels combined with simple dosimetry models.

2962. Hrs-Brenko, M., C. Claus, and S. Bubic. 1977. Synergistic effects of lead, salinity and temperature on embryonic development of the mussel *Mytilus galloprovincialis*. Marine Biology 44:109-115.

Combined effects of lead, salinity and temperature on embryonic development of mussels were studied under laboratory conditions. The basic experimental design was a 4 x 6 factorial experiment using 4 lead concentrations (100, 250, 500 and 1000 ug Pb^{2+}/l) and 6 salinity levels (from 25 to 37.5 o/oo with 2.5 o/oo intervals). These factorial studies were conducted at 3 constant temperatures (15, 17.5 and 20 C). Statistical analysis indicated that salinity changes have more effect on embryonic development than temperature. Optimal development was observed at 34.8 o/oo and 15.6 C, which is in accordance with observations in the field. The effect of lead was minimal in optimal salinity and temperature conditions. The deleterious effect of lead on embryonic development was especially conspicuous at 20 C. Since in nature spawning occurs at temperatures lower than 20 C, lead will probably not drastically decrease the potential recruitment of mussel spat in littoral populations of the northern Adriatic Sea, where salinity of the water is relatively stable. Under experimental conditions, lead caused a delay or inhibition of embryonic development with occurrence of a large number of abnormal larvae.

2963. Ireland, M.P. 1977. Lead retention in toads Xenopus laevis fed increasing levels of lead-contaminated earthworms. Environ. Pollution 12:85-92.

Toads were fed, at a fixed rate, live earthworms containing 10, 308, and 816 mg/kg wet wt lead. All six toads in each group were killed after 4 or 8 weeks and the tissues analyzed for lead. The highest concentration of dietary lead had no significant effect on growth rate, hemoglobin, hematocrit or reticulocyte values, but it did significantly affect levels of delta-aminolevulic acid dehydrase. There was significantly less lead in bone, skin, kidney, and liver in toads on a low lead diet compared with toads on higher lead diets; there was no significant difference in muscle lead. Individual organ analysis, within groups, showed high levels of lead in kidney, bone and liver, but low lead values in skin and muscle. The ratio of bone lead concentration to kidney, liver and muscle lead, compared with deer mice, showed more lead was deposited in soft tissues of toads. Author suggests that toads present a relatively high lead pollution hazard in the food chain.

2964. Ireland, M.P. and R.J. Wootton. 1977. Distribution of lead, zinc, copper and manganese in the marine gastropods, Thais lapillus and Littorina littorea, around the coast of Wales. Environ. Pollution 12:27-41.

Two species of marine gastropods were taken in August 1974 from 9 sites around the coast of Wales and analyzed for Pb, Zn, Cu, and Mn. Significant species and site differences could be detected and are discussed in relation to known polluted areas and species specificity for metals. Site X species interactions were inconsistent. Metal content of whole bodies, in mg/kg dry wt, of Thais from each site ranged from 492 to 2355 for Zn, 166 to 458 for Cu, 5.9 to 17.3 for Mn, and 3.9 to 19.6 for Pb; in Littorina, levels ranged from 92 to 186 for Zn, 43 to 249 for Cu, 19 to 60 for Mn, and 4.0 to 15.0 for Pb. Tissue metal analysis of specimens from selected areas showed high levels of zinc and copper in digestive gland/gonad of Thais (up to 761 mg Zn/kg zinc and 554 mg Cu/kg) compared with Littorina (134 Zn, 92 Cu), and high levels of manganese in digestive gland/gonad of Littorina (up to 104 mg/kg) compared with Thais (8.5 mg/kg). Highest level of lead in both species was found in shell, at 45 mg Pb/kg for Thais and 42 for Littorina. Manganese was greater in shells of Littorina (up to 8.3 mg/kg) than in Thais (4.2 mg/kg). Results are discussed in relation to possible food source and mineralogy of shell, together with the presence of specific enzyme systems.

2965. Itazawa, Y. and J. Koyama. 1978. Effects of oral administration of cadmium on fish - III comparison of the effects on the porgy and the carp. Bull. Japan. Soc. Sci. Fish. 44:891-895. (In Japanese, English abstract).

Porgy, Pagurus major, of 73 g, were fed for 113 days diets containing 0.0, 37.5, 150, or 375 mg/kg dry wt of cadmium. There was no decrease in serum calcium and vertebrae Ca, or of scoliosis, all of which were noticed in carp fed diets containing $\geq$140 mg Cd/kg for 30 days. Alkaline phosphatase activity and magnesium concentration in serum, and phosphorus and magnesium in vertebrae all increased slightly in porgy fed 375 mg Cd/kg. Total amount of Cd administered per 100 g of fish through the feeding period was 42.4 mg for porgy on 375 mg/kg Cd-feed, and 3.8-5.6 mg for carp fed on 140 mg/kg. Cd contents, in mg/kg, in porgy fed 375 mg Cd/kg were 0.0 in muscle and gills, 64 in digestive tract, 146 in hepatopancreas, and 164 in kidney. Cd levels in carp fed 150 mg Cd/kg were 0.0 muscle, 0.6 spleen, 139 digestive tract, 14 hepatopancreas, and 52 kidney. That porgy, a marine teleost, did not suffer from low calcium and vertebral abnormalities even when administered 7 to 11X more Cd than carp, is considered to be due partly to calcium that carp derived from the environmental medium.

2966. Jasper, P. and S. Silver. 1978. Divalent cation transport systems of Rhodopseudomonas capsulata. Jour. Bacteriology 133:1323-1328.

Separate transport systems for energy-dependent uptake of Mg^{2+} and Mn^{2+} were found with aerobically, heterotrophically, and photosynthetically grown cells of R. capsulata. The maximum rate of Mg^{2+} uptake differed between photosynthetic and aerobic cells, while the K_m for the Mg^{2+} transport system was constant. Photosynthetic midlog-phase cells exhibited K_m's for uptake of about 55 uM Mg^{2+} and 0.5 uM Mn^{2+}. The V_{max}'s also differed between the two systems: 0.6 to 1.8 umol/min per g (dry wt) of cells for Mg^{2+}, but only 0.020 umol/min per g for Mn^{2+}, distinguishing between a "macro-requirement" system and a system functioning at trace nutrient levels. Calcium was not normally taken up by intact cells of R. capsulata. However, chromatophore membranes isolated from photosynthetic cells took up Ca^{2+} by an energy-dependent process.

2967. Johnson, D.L. and R.M. Burke. 1978. Biological mediation of chemical speciation. II. arsenate reduction during marine phytoplankton blooms. Chemosphere 8:645-648.

The thermodynamically unfavorable arsenite form, As^{3+}, occurs in seawater to a much greater extent than can be accounted for by thermodynamic equilibrium. Accordingly, authors formulated a temporal steady state model balancing chemical, biological, and physical forces to explain its existence there. Since elements, including As, with sufficient biological involvement change in chemical speciation due to changes in "suitable" biological parameters of an ecosystem, authors determined chemical speciation of arsenic in water column during a winter-spring diatom bloom in Narragansett Bay, R.I. Populations of phytoplankton, Skeletonema costatum, had a peak of 10,000 cells/ml in November 1976 and a higher peak of 30,000 cells/ml in March 1977. Total arsenic in water remained relatively constant at about 975 ng/l from Nov. to April. Arsenite water levels increased relative to arsenate during the winter-spring bloom; $As^{3+}:As^{5+}$ ratios generally increased from 0.02 to 0.08. Ratio of orthophosphate to arsenate had corresponding decreases at algal blooms, showing a decrease in P^{5+}. Rate of arsenate transport by uptake systems in algae will increase as P/As^{5+} ratio falls, since arsenate competitively inhibits phosphate uptake. Arsenite production reached 2.25 to 3.38 ug/l between days 10 and 40 for Skeletonema grown with 3.98 ug/l arsenate and phosphate concentrations of 370 to 1580 ug/l; higher As^{3+} peaks appeared sooner in higher P levels.

2968. Kallqvist, T. and B.S. Meadows. 1978. The toxic effect of copper on algae and rotifers from a soda lake (Lake Nakuru, East Africa). Water Research 12:771-775.

The effect of Cu^{2+} ions on the photosynthetic oxygen production of phytoplankton, the growth rate of the blue-green algae Spirulina platensis and the population of rotifers Brachionus sp. in water from Lake Nakuru in Kenya was investigated. Within 8 days, the photosynthetic production was reduced to 80% of control by addition of 0.1 mg Cu/l and 50% by 0.15-0.20 mg Cu/l. Growth rate of Spirulina was more affected by copper than photosynthesis of phytoplankton. Addition of 0.05 mg Cu/l reduced growth rate to about 40% of control. Rotifers were less sensitive to copper than the algae; but after 8 days exposure to 0.5 mg Cu/l or more the population was reduced to 0-4 specimens/ml compared to 35-51/ml in lesser Cu concentrations.

2969. Korda, R.J., T.E. Henzler, P.A. Helmke, M.M. Jimenez, L.A. Haskin, and E.M. Larsen. 1977. Trace elements in samples of fish, sediment and taconite from Lake Superior. Jour. Great Lakes Res., Internat. Assn. Great Lakes Res. 3:148-154.

Concentrations of Cu, Zn, Mn, Na, As, Hg, Co, Sc, Cd, Se, Fe, Cr, and 15 rare-earth elements were determined in samples of flesh and liver from two species of sculpin, sediment, and taconite tailings. The samples were from areas of Lake Superior with high and low concentrations of taconite tailings. Sediment from the top 2 cm to a depth of 41 cm contained metal concentrations, in mg/kg, ranging from 6 to 109 for As, 60 to 115 for Ce, 18 to 25 for Co, 70 to 150 for Cr, 40 to 72 for Cu, 51,000 to 202,000 for Fe, 12 to 24 for Ga, 635 to 2300 for Mn, 7250 to 14,300 for Na, 28 to 49 for Nd, 9 to 17 for Sc, and 80 to 160 for Zn; Dy, Er, Eu, Gd, Hf, Ho, Lu, Sm, Tb, and Yb levels were all <10 mg/kg. Concentrations of all elements, except Mn, in 0-2 cm sediment samples were lower than samples at 16-17.5 cm and 37-41 cm; samples at 3.5-3.7 cm had lowest concentrations for all metals except As, Fe, and Mn. Only As and Mn concentrations in taconite tailings were higher than in sediment. The low concentrations of most trace elements in taconite and the similarity of their concentration ratios show that no elements measured in taconite are suitable for use as tracers to determine movement and distribution of taconite tailings in Lake Superior. No significant differences were found in trace element concentrations in sculpin from the site affected by taconite tailings compared to those not affected. Maximum metal concentrations, in mg/kg wet wt, in sculpins *Cottus cognatus* and *Myoxocephalus quadricornis* from all sites were, in flesh, 0.02 for Co, 0.76 for Cu, 0.63 for Mn, 790 for Na, 12.3 for Zn, 0.12 for As, 0.02 for Cd, 0.35 for Hg, 0.59 for Se, and between 0.0002 to 0.0027 for Ga, La, Sb, Sc, and Sm. Sculpin liver contained maximum levels, in mg/kg wet wt, of 0.14 for Co, 3.7 for Cu, 1.4 for Mn, 1360 for Na, 39 for Zn, 0.59 for As, 0.81 for Cd, 0.28 for Hg, 1.7 for Se, and between 0.0007 to 0.0045 for Ga, La, Sb, Se, and Sm.

2970. Kotani, H., A. Shinmyo and T. Enatsu. 1977. Killer toxin for sake yeast: properties and effects of adenosine 5'-diphosphate and calcium ion on killing action. Jour. Bacteriology 129:640-650.

The killer character of a strain isolated from the main mash of sake brewing which produces a killer substance for sake yeast was transmitted to hybrids of the strain and a standard strain of *Saccharomyces cerevisiae*. The character was eliminated at 41 C by incubation followed by growth at 30 C. The killer strain produced the killer toxin in a growth-associated manner. A preparation of crude killer toxin extract showed first-order inactivation and a linear Arrhenius plot between 25 and 40 C, with an activation energy of 55.0 kcal/mol. Addition of 1% of synthetic polymer protected the toxin from inactivation by agitation but not by heat. Enhancement of the killer action toward sensitive yeast cells by only the nucleotide adenosine 5'-diphosphate (ADP) was observed after plating on agar medium as well as after incubation in liquid medium. The addition of $CaCl_2$ reversed the enhancing effect of ADP on killing activity. This action of $CaCl_2$ was inhibited by cycloheximide, suggesting the protein synthesis is required for recovery of toxin-induced cells in the presence of $CaCl_2$. Further, $CaCl_2$ overcame the decrease in the intracellular level of adenosine 5'-triphosphate (ATP) enhanced by ADP in killer-treated cells and also inhibited leakage of ATP from the cells with immediate response. The mode of killing action is discussed in terms of a transient state of the cells and the action of ADP and $CaCl_2$.

2971. Kumagai, H. and K. Saeki. 1978. Contents of total mercury, alkyl mercury and methyl mercury in some coastal fish and shells. Bull. Japan. Soc. Sci. Fish. 44:807-811. (In Japanese, English summary).

Average total mercury levels, in mg/kg wet wt, in edible portions of marine organisms collected near Yamaguchi were 0.069 for 30 species of fish, 0.078 for 4 species of crustaceans, 0.058 for 3 species of cephalopod molluscs, and 0.041 for 5 species of bivalve and gastropod molluscs. Wide within-group variation occurred for total mercury. No lower alkylmercuric compounds were detected, except methylmercury. Authors suggest that content of lower alkylmercury coincides with methylmercury in uncontaminated coastal water samples. Mean concentrations of methylmercury in edible portions were 0.046 mg/kg for fish, 0.009 for crustaceans, 0.025 for cephalopods, and 0.008 for bivalves and gastropods. Ratios of methylmercury to total mercury were 0.67, 0.46, 0.70, and 0.18 for respective groups.

2972. Labat, R., C. Roqueplo, J.-M. Ricard, P. Lim and M. Burgat. 1977. The ecotoxicological action of some metals (Cu, Zn, Pb, Cd) on freshwater fish in the river Lot. Annls. Limnol. 13:191-207. (In French, English abstract).

Poisoning of fish by heavy metals (Cu, Zn, Pb, and Cd) is most common in populations downstream from the source of pollution. In downstream zones, there is a passive accumulation of metals by fish related to the low concentration of these metals in water. Water at 9 stations along the river contained trace to 0.03 mg Cu/l, 0.03 to 3.1 mg Zn/l, trace to 0.09 mg Pb/l, and trace to 0.24 mg Cd/l. Metal concentrations in muscle of 15 fishes (*Lucioperca lucioperca*, *Esox lucius*, *Micropterus salmoides*, *Perca fluviatilis*, *Lepomis gibbosus*, *Leuciscus leuciscus*, *L. cephalus*, *Rutilus rutilus*, *Scardinius erythrophtalmus*, *Chondrostoma toxostoma*, *Alburnus alburnus*, *Gobio gobio*, *Ciprinus carpio*, *Barbus barbus*, and *Tinca tinca*) at these stations ranged from 2.0 to 71.0 mg Cu/kg, 15.8 to 75.5 for Zn, 0.1 to 1.6 for Pb, and 0.04 to 18.0 for Cd. Maximum values were found at the 5 sites furthest downstream from the contamination source. Because fish accumulate metals from water, authors suggest that there should be three critical thresholds for the content of metals in water, each one affecting a different physiological process. Contamination with metals affected absorption through gills and food absorption with a gradient through the gut.

2973. Lande, E. 1977. Heavy metal pollution in Trondheimsfjorden, Norway, and the recorded effects on the fauna and flora. Environ. Pollution 12:187-198.

During 1972-73, molluscs (*Mytilus edulis*, *Patella vulgata*), crustaceans (*Carcinus maenas*) and seaweeds (*Ascophyllum nodosum*, *Fucus vesiculosus*, *Pelvetia canaliculata*) from the intertidal zone, and pelagic and bottom-dwelling fishes (*Gadus* spp., *Anarchichas lupus*, *Clupea harengus*, *Macrurus rupestris*, *Chimaera monstrosa*, *Glyptocephalus cynoglossus*, *Galeus melastomus*, *Argentina silus*, *Etmoterus spinax*) were sampled. Seabirds (*Somateria mollissima*, *Larus fuscus fuscus*) were collected in the fjord and from adjacent areas. Kidneys, liver, pectoral musculature and eggs (white and yolk) of these birds were analyzed. All samples were analyzed for cadmium, copper, iron, nickel, chromium, silver, zinc and mercury. Heavy metal pollution was found in two distinct areas of the fjord. Qualitative and quantitative changes in the faunal assemblages of these two areas are described.

2974. Livingston, H.D. and V.T. Bowen. 1976. Americium in the marine environment - relationships to plutonium. *In:* Miller, M.W. and J.N. Stannard (eds.). *Environmental* toxicity of aquatic radionuclides: models and mechanisms. Ann Arbor Sci. Publs., Inc.:107-130.

The behavior of Am-241 in the marine environment, and by analogy other transplutonium nuclides, is compared and contrasted with that of Pu-239,240. Radiochemical data for these nuclides in seawater, sediments, and organisms contaminated mostly by global fallout, are used to generate the ratio Am-241/Pu-239,240, used as an index of fractionation between plutonium and americium. The average value for this ratio, 0.20, found in shallow nearshore sediments is proposed as representative of integrated, unfractionated fallout at mid-latitudes in the Northern Hemisphere by mid-1973. No fractionation between Am and Pu has been found in these sediments, even under conditions when they are being lost from the sediment following upward vertical migration. Higher ratios in deep ocean water and sediments suggest that americium sinks more quickly than plutonium in the water column. Data reported for some marine organisms, mostly algae but also plankton, corals, clams, and fish, suggest that while americium may frequently be concentrated to a degree similar to plutonium, some organisms may discriminate against, and others in favor of, americium relative to plutonium. Authors measured ratios of Am-241/Pu-239,240 ranging from 0.04 to 0.23 in the algae

Sargassum sp., *Fucus vesiculosa*, *Desmaidetta* sp., *Daisia* sp., and *Chondrus crispus* from the Massachusetts coast, and 0.10 in starfish, *Asterias forbesi*, 0.15 in urchin (*Strongylocentrotus drobachiensis*) spines, and 0.29 in winkle (*Buccinum undatum*) shells.

2975. Luoma, S.N. and G.W. Bryan. 1978. Factors controlling the availability of sediment-bound lead to the estuarine bivalve *Scrobicularia plana*. Jour. Marine Biol. Assn. U.K. 58:793-802.

Concentrations of lead in soft tissues of the deposit-feeding clam, *S. plana*, were compared with physicochemical characteristics of sediments in 20 estuaries in southern and western England and one in northwest France. Biological availability of lead in sediment is controlled mainly by the concentration of iron. Lead concentration in bivalves may be predicted from the Pb/Fe ratio in 1 N HCl acid extracts of surface sediments. Maximum tissue lead of 1000 mg/kg dry wt was found in clams collected from sediments containing maximum Pb at slightly over 1000 mg/kg, high Fe at 6000 mg/kg, and maximum Pb(mg/kg)/Fe(g/kg) ratio of almost 200.

2976. Matthiessen, P. and A.E. Brafield. 1977. Uptake and loss of dissolved zinc by the stickleback *Gasterosteus aculeatus* L. Jour. Fish Biology 10:399-410.

Uptake and loss by sticklebacks of both stable zinc and Zn-65 in hard and soft water were studied for periods up to 400 hr. In calcium-free water, the Zn-65 uptake curve is approximately asymptotic over a period of 24 hr, while in hard water internal Zn-65 levels begin to drop by 24 hr. Over 5 hr, however, fish in hard tapwater absorb about 3.5 times more Zn-65 than those in calcium-free water. There is a positive linear relationship between log Zn-65 uptake and log wet wt of fish. Whole body concentration factors (CF) at 16 hr reach a maximum of 12.2 (mean = 2.9), with the highest concentrations of Zn-65 found in the gills (mean CF = 5.1) and the lowest concentrations in gonads (mean CF = 0.8). Over longer periods (400 hr), internal stable zinc levels of fish exposed to 1.0 and 4.0 mg Zn^{2+}/l remain slightly higher (max 28%) than controls. Zn-65 efflux into zinc-free water falls to zero after 5 hr, more zinc (78%) being lost after uptake in tapwater than in Ca-free water (56%).

2977. Maximov, V.N. 1977. Specific problems in studyies (sic) of pollutants combined action on biological systems. Gidrobiologicheskii Zhurnal 13(4):34-45. (In Russian, English summary).

Problems associated with toxicity of mixtures of $ZnCl_2$ and K_2CrO_4 to marine alga, including *Skeletonema costatum*, *Chaetoceros wighamii*, *Dynobrion pellucidum*, *Gymnodinium arcticum*, and diatoms *Nitzschia* spp. were investigated.

2978. Merlini, M. and G. Pozzi. 1977. Lead and freshwater fishes: part I - lead accumulation and water pH. Environ. Pollution 12:167-172.

The accumulation of lead-203 by the sunfish, *Lepomis gibbosus*, an edible freshwater teleost, was investigated at pH 7.5 and pH 6.0. At the lower pH, fish concentrated almost 3X more lead than at the higher pH. Maximum Pb-203 accumulations were observed in gills, fins and liver; minimal accumulations in muscle; and intermediate accumulations in skin and scales, head, and bone. The sites of lead concentration, however, were not altered by change in water pH.

2979. Mitchell, N.T. 1977. Radioactivity in surface and coastal waters of the British Isles, 1976. part I. the Irish Sea and its environs. Tech. Rep. Fish. Radiobiol. Lab., MAFF Direct. Fish. Res., (FRL 13) Lowestoft:15 pp.

Measurements of radioactivity of Am-241, Ce-144, Cs-134, Cs-137, Pa-234m, Pu-239+240, Ru-106, and Zr-95/Nb-95 were recorded in seawater, sediments and biota including algae, crustaceans, bivalve and gastropod molluscs, and fish from various locations in the Irish Sea in 1976. Maximum individual public radiation exposures from disposals of liquid radioactive wastes, as % of ICRP-recommended dose limit of 33 millirem/person/yr, were: 44% from fish and shellfish at Windscale Nuclear Fuel Limited, 8% from external dose at Windscale, 0.2% from *Porphyra* seaweed-laverbread pathway at Windscale, and <1.0% of exposure limits at Springfields and Chapelcross Nuclear Fuel Limited outfalls. Wylfa Electricity Generating Board discharge accounted for <0.1% of dose limit.

2980. Mitra, R.S. and I.A. Bernstein. 1978. Single-strand breakage in DNA of *Escherichia coli* exposed to Cd^{2+}. Jour. Bacteriology 33:75-80.

When a growing culture of *E. coli* was exposed to 3×10^{-6} M Cd^{2+} (about 0.34 mg Cd/1), 85 to 95% of the cells lost their ability to form colonies on agar plates. Loss of viability was accompanied by considerable single-strand breakage in the DNA, with no detectable increase in double-strand breaks. A direct correlation exists between number of single-strand breaks and the concentrations of Cd^{2+} to which the cells were exposed. Exposure of DNA *in vitro* to a Cd^{2+} concentration of 3×10^{-6}M or higher, followed by sedimentation in alkaline sucrose gradients, demonstrated no single-strand breaks. Cadmium-exposed cells recovered viability when incubated in Cd^{2+}-free liquid medium containing 10 mM hydroxyurea. During the early period of recovery, there was a lag in the incorporation of labeled thymidine, but cellular DNA, at least in part, appeared to be repaired.

2981. Muller, G. 1978. Strontium uptake in shell aragonite from a freshwater gastropod. Naturwissenschaften 65:434.

Mean distribution coefficients relating Sr/Ca ratios in shell aragonite to Sr/Ca ratios in water ranged from 0.233 to 0.282 for gastropod molluscs of the genera *Lymnaea*, *Planorbis*, *Bithynia*, and *Valvata* in Lake Constance, Germany. Distribution coefficients ranged from 0.307 to 0.378 in pelecypod molluscs *Anodonta*, *Sphaerium*, and *Pisidium*. Coefficients of Sr/Ca ratios averaged 0.252 in all gastropods and 0.348 in all pelecypods.

2982. Murphy, B.R., G.J. Atchison, A.W. McIntosh and D.J. Kolar. 1978. Cadmium and zinc content of fish from an industrially contaminated lake. Jour. Fish Biology 13:327-335.

Eleven species of fish from the industrially-contaminated Palestine Lake were analyzed for whole body cadmium and zinc. Species were bluegill *Lepomis macrohirus*, redear *L. microlophus*, warmouth *L. gulosus*, orangespot sunfish *L. humilus*, largemouth bass *Micropterus salmoides*, black crappie *Pomoxis nigromaculatus*, golden shiner *Notemigonus crysoleucas*, white sucker *Catostomus commersoni*, brown bullhead *Ictalurus nebulosus*, bowfin *Amia calva*, and yellow perch *Perca flavescens*. Most species accumulated Cd and Zn to levels significantly higher than background. At the electroplating plant discharge, water levels were 17.3 ug/l dissolved Cd, 30.3 ug/l suspended Cd, and 293 and 270 ug/l dissolved and suspended Zn. Sediment contained 800 mg Cd/kg dry wt and 12,800 mg Zn/kg. Mean metal content in fish collected near the discharge ranged from 0.06 to 8.0 mg Cd/kg dry wt, with an individual maximum of 13.6 in bluegill, and from 80 to 477 mg Zn/kg dry wt, with a maximum of 820 in redear. Away from the discharge, water levels, in ug/l, were 0.9 dissolved Cd, 0.3 suspended Cd, 52.4 dissolved Zn, and 5.2 suspended Zn. Concentrations in sediments, in mg/kg dry wt, were 4.4 Cd and 320 Zn; and body levels in fish, in mg/kg dry wt, ranged from below detection to 0.21 for Cd, and 79 to 139 for Zn. Cadmium content was much more variable than zinc. Distributions of concentrations of both cadmium and zinc in fish were lognormal, and concentrations of both metals tended to decrease in higher trophic levels. Zinc concentrations significantly decreased as total length increased in three species.

2983. Ociepa, A. and M. Protasowicki. 1976. A relationship between total mercury content and a kind of food in some chosen Pacific fish species. Marine Fishing Food Technol. 60:83-87. (In Russian, English Summary).

Mercury determinations in 5 species of Pacific foodfish: Trachurus symmetricus, Theragra chalcogramma, Merluccius productus, Hypomesus pretiosus, and Sebastes sp., caught off the western coast of the USA are presented. Mercury content varied in flesh of the species examined, from 0.0 to 1.9 mg/kg, but the average never exceeded 0.3 mg/kg wet wt for individual species. Mercury in planktophagous and predatory fishes were different and suggests an increasing accumulation of Hg in consecutive links of trophic chains.

2984. Pascoe, D. and P. Cram. 1977. The effect of parasitism on the toxicity of cadmium to the three-spined stickleback Gasterosteus aculeatus L. Jour. Fish Biology 10:467-472.

Toxicity of cadmium to sticklebacks was determined over a wide range of concentrations. LC-50 (96 hr) was 6.5 mg Cd/l. The shape of the time-concentration curve suggests that cadmium may have two toxic mechanisms. The median period of survival for fish infected with the plerocercoids of the cestode, Schistocephalus solidus, was found to be considerably shorter than for non-parasitized fish. This observation is considered in the light of known effects of S. solidus on its host.

2985. Paul, A.C. and K.C. Pillai. 1978. Pollution profile of a river. Water, Air, Soil Poll. 10:133-146.

A host of chemical industries subject the Periyar River in south India to pollutants such as acids, bases, trace metals and radionuclides. Proximity of different outfalls and poor lateral mixing in the river are responsible for high local aquatic concentrations. Scavenging reactions, in situ, and sedimentation of suspended matter result in accumulation of radionuclides near the outfall area. Monsoon rains flush the river into the backwater area, with translocation of sediments being the major factor in pollutant transport. Relative concentration values of metal concentrations at outfalls compared to background levels in 1974-75 were: Ra-288, 15 water and 500 sediment; Cd, >400 water and >8750 sediment; Cu, 6.0 and 1.0; Hg, >23 and >3600; Mn, 180 and 4.0; and Zn, >3750 and 220, respectively. Sediment concentrations of Ca, Co, Cr, Fe, K, Mg, and Ni were determined at various sites before and after monsoons. Ra-228, Cd, and Hg are preferentially concentrated in sediments, whereas Zn, Cu, and Mn are concentrated in water. Levels of Ra-228, in uCi/kg, and Hg, in mg/kg, in fish flesh were 0.15 and 0.1, respectively, in Aries sp.; 0.14 and 0.2 in Clupea longicents; and 0.05 and 0.1 in Etroplus sp. Etroplus viscera contained 2.2 uCi Ra-228/kg.

2986. Pentreath, R.J. 1977. The accumulation of cadmium by the plaice, Pleuronectes platessa L., and the thornback ray, Raja clavata L. Jour. Exp. Marine Biol. Ecol. 30:223-232.

Accumulation of cadmium-115m from both food (polychaete worms Nereis sp.) and seawater by a flatfish, Pleuronectes platessa, and thornback ray, Raja clavata, was studied in relation to measured cadmium concentrations. Plaice accumulated cadmium from seawater at a faster rate than rays, although concentration factors attained by both species as a result of such direct accumulation were very low. CF factors for plaice tissues after 59 days were 125 for gill filament, 115 for upper intestine, 46 for lower intestine, 16 for liver, 6 for stomach and <1 for skin, muscle, and bone. CF for rays after 70 days were 9 for gill filament, 3 for liver, and <1 for all other tissues. Both species retained cadmium from food and accumulated it in the liver, with rays accumulating more than plaice. Some evidence was found for a positive linear relation between concentrations of cadmium in plaice liver and age, but not weight, of the fish.

2987. Pentreath, R.J. and M.B. Lovett. 1976. Occurrence of plutonium and americium in plaice from the north-eastern Irish Sea. Nature 262:814-816.

Highest concentrations of plutonium (Pu-238,-239,-240) in the internal organs of fish (Pleuronectes platessa) collected in February 1975 from the vicinity of a nuclear fuel reprocessing facility was in kidneys. Fish caught later in the year exhibited higher values for gut, and this was attributed to the low feeding frequency in winter. Concentrations of Am-241 in the internal organs were generally higher than those of plutonium. In any event, the concentrations of Pu and Am isotopes measured in fish muscle are equivalent to less than 0.01% of the derived working limit, based on calculations using a dose limit to the public of 3 rem/year and maximum consumption rate of 300 g fish/day.

2988. Rho, S. and C.K. Park. 1976. Studies on the propagation of blue crab, Portunus trituberculatus (Miers) (1) the survival of larvae stages to various salinities. Bull. Fish. Res. Dev. Agency 15:43-56. (In Japanese, English summary).

Survival of blue crab larval stages in different salinity concentrations was observed. In salinity lower than 9 o/oo all zoeal larvae were dead after 48 hrs incubation. Survival increased as salinity increased from 9 to 33 o/oo. Above 21 o/oo S, approximately 70% of zoeae survived. Survival rates of megalopa larvae were similar to zoeal larvae. The lowest survival of 15 percent was observed at 12 o/oo S. Survival of young crab stage 5 (ecdysis) was 90% at 9 o/oo salinity.

2989. Rodsaether, M.C., J. Olafsen, J. Raa, K. Myhre, and J.B. Steen. 1977. Copper as an initiating factor of vibriosis (Vibrio anguillarum) in eel (Anguilla anguilla) Jour. Fish Biology 10:17-21.

Eels (Anguilla anguilla) which were exposed to copper-contaminated freshwater (30-60 ug Cu/l) died with symptoms of vibriosis (Vibrio anguillarum). Eels kept in non-contaminated freshwater (<6 ug Cu/l) remained healthy. V. anguillarum was present in eels with symptoms of vibriosis. Authors suggest that V. anguillarum is a common inhabitant of eels and that copper can change a commensal association between fish and bacterium to one of pathogenicity. Maximum concentrations of copper recorded in tissues of eels surviving exposure to copper-contaminated water for 50 days at 2 to 4 C were about 50 mg/kg wet wt in liver and about 140 mg/kg wet wt in brain.

2990. Schmidt, R.L. 1978. Copper in the marine environment - part I. CRC Critical Rev. Environ. Control 8:101-152.

This compendium of the literature describing the biogeochemistry of copper in the marine environment examines abiotic and biotic factors that affect distribution and cycling of copper in the marine ecosystem. Emphasis is placed on transformations of copper by physicochemical processes and its transfer between components within the ecosystem. The inorganic and organic chemistry of copper in the marine environment are discussed. A summary is presented of techniques for extracting and concentrating copper from environmental samples and of procedures for analytical measurement. Sources of copper to the sea are identified and the concentrations and forms of copper are given for seawater, suspended particulates, detritus, sediments, and some marine organisms, such as plankton and molluscs, collected throughout the world's oceans. A bibliography of about 870 titles is appended.

2991. Schmidt, R.L. 1978. Copper in the marine environment - part II. CRC Critical Rev. Environ. Control 8:247-291.

This compendium of the literature (a bibliography of about 400 articles is appended) describing the biogeochemistry of copper in the marine environment, examines abiotic and biotic factors that affect distribution and cycling of copper and ecological implications of this metal in the marine ecosystem. Emphasis is placed on transformations of copper by physicochemical and biological processes; its transfer between components within the ecosystem; and the availability, uptake and effect of copper on marine biota. The inorganic and organic chemistry of copper in the marine environment are discussed. Sources of copper to the sea are identified and the concentrations and forms of copper are given for seawater, suspended particulates, sediments, and some marine organisms, including bacteria, phytoplankton, algae, annelids, echinoderms, crustaceans, molluscs, and fish collected throughout the world's oceans. Seaweeds, polychaete worms, mussels, and oysters appear to have fairly consistent Cu accumulation factors and reflect environmental concentrations. Cu is generally concentrated in digestive organs of most animals except molluscs and arthropods, whose blood contains hemocyanin, a Cu-protein. Uptake of copper by phytoplankton is probably an active process, whereas seaweeds simply absorb metals. Dietary uptake is the most important means of Cu accumulation for most marine animals. Polychaetes directly adsorb Cu from sediment interstitial water. Oysters bind the metal in gill mucous sheets. Complexation of copper by nonviable cellular materials reduces toxicity to bacteria and phytoplankton, and may regulate Cu seawater levels. Some animals, particularly polychaetes and fish, may influence the biogeochemistry of Cu in shallow estuaries.

2992. Schulz-Baldes, M. and R.A. Lewin. 1976. Lead uptake in two marine phytoplankton organisms. Biol. Bull. 150:118-127.

Uptake of lead by diatoms, Phaeodactylum tricornutum, and flagellate algae, Platymonas subcordiformis, exposed to lead concentrations ranging from 0.02 to 0.8 mg/l occurs in two phases. The first phase, completed within 10 minutes after addition of lead, can be described by a Freundlich adsorption isotherm. The number of binding sites per cell seems to be limited. Cells of Phaeodactylum become "saturated" when lead burden reaches 11,640 mg/kg dry wt, equivalent to about 6.7 x 10^8 Pb atoms per cell. In the second phase, lead content of Platymonas cells continues to rise slowly, whereas that of Phaeodactylum declines after two or three days. Addition of 0.000002 M EDTA to a solution containing 1.0 mg Pb/l completely inhibits metal uptake by Phaeodactylum. When diatom cells, pre-treated with lead, are resuspended in a higher concentration of 0.01 M EDTA, much of the adsorbed lead is eluted. The longer the pre-treatment period with lead, the less readily is the metal removed from cells in this way. Since content of bound lead, i.e. residual lead burden after EDTA extraction, increases with time in both species, authors suggest that, during prolonged exposure to lead solutions, metal ions are first adsorbed to the cell surface and then translocated to within the cell wall, to plasma membrane, and eventually to cytoplasm.

2993. Shcherban, E.P. 1977. Toxicity of some heavy metal ions for Daphnia magna Straus depending on temperature. Gidrobiologisheskii Zhurnal 13(4):86-91. (In Russian, English summary).

Effect of cadmium, copper, manganese, nickel, and zinc sulphates on 3- to 5-day fry and puberal females of D. magna was studied for 24, 48, and 72 hours at temperatures of 10, 15, 25, and 30 C. Toxicity of each ion increased with increasing temperature and length of exposure. Between 25 and 30 C, Cd toxicity rose 3-4 orders of magnitude and Cu and Zn by 2 orders, while Ni and Mn were only slightly more toxic.

2994. Sheffy, T.B. 1978. Mercury burdens in crayfish from the Wisconsin River. Environ. Pollution 17:219-225.

Mercury in abdominal muscle of crayfish, Orconectes virilis, from the Wisconsin River ranged from 0.07 to 0.56 mg/kg wet wt. Elevated Hg concentrations did not correspond with the industrialized zone along the river. The pattern of mercury accumulation in crayfish was similar to that of sediment, fish, and mammals previously recorded along the Wisconsin River. Crayfish, therefore, seem to be a useful indicator species of mercury contamination along a river system, since crayfish are easily obtained and provide a basis for organic mercury accumulation for other species from the same area.

2995. Shiber, J.G. and T.A. Shatila. 1978. Lead, cadmium, copper, nickel and iron in limpets, mussels and snails from the coast of Ras Beirut, Lebanon. Marine Environ. Res. 1:125-134.

Limpets Patella coerulea, mussels Brachydontes variabilis, snails Monodonta turbinata, and surface seawater were collected at eight locations along the coast of Ras Beirut, Lebanon, and analyzed for lead, cadmium, copper, nickel, and iron. With the exception of cadmium, metal levels found in the three molluscs appear to be high in relation to levels reported by investigators from other coastal areas. Average values for lead, cadmium, and nickel in these animals were quite similar, although Patella had higher iron and lower copper content. Average metal concentrations, in mg/kg dry wt, in soft parts of Patella were 37.8 for Pb, 2.5 for Cd, 22.8 for Cu, 40.1 for Ni, and 2685.0 for Fe; concentrations in Brachydontes were 53.0, 1.6, 98.4, 37.0, and 517.0, respectively, and in Monodonta 31.8, 1.1, 87.1, 27.4, and 737.0, respectively. Average seawater levels were 0.36 mg Pb/l, 0.02 for Cd, 0.15 for Cu, 0.27 for Ni, and 8.1 for Fe.

2996. Singh, S.M. and P.N. Ferns. 1978. Accumulation of heavy metals in rainbow trout Salmo gairdneri (Richardson) maintained on a diet containing activated sewage sludge. Jour. Fish Biology 13:277-286.

Trout were fed for 10 weeks with a nutritionally balanced diet containing 30% by weight of activated sewage sludge. The experimental diet contained 9.2 mg Cr/kg dry wt, 171.0 Mn, 2340.0 Fe, 5.4 Co, 61.0 Ni, 61.0 Cu, 167.0 Zn, 1.1 Cd, 38.0 Pb, 10,700.0 Ca, 1780.0 Mg, 798.0 Na, and 1690.0 K. Whole body concentrations were determined at the beginning and end of the experiment and at three intermediate stages. Fish fed the diet containing sewage sludge had significantly elevated levels of Cr, Fe, Ni, Pb, and reduced levels of Na and K after 70 days, though the values obtained for all groups fell within the range reported for uncontaminated fish. Chromium concentration in fish was 3.6 mg/kg dry wt compared to 2.8 in controls, iron was 45.9 compared to 37.3, nickel was 0.63 vs. 0.33, and Pb was 0.78 compared to 0.45. Nickel and Zn showed a marked increase towards the end of the experiment, suggesting that they might have continued to rise after 70 days. Weight gain was 7.6% in contaminated fish compared to 11.6% in uncontaminated fish.

2997. Sodergren, S. 1976. Ecological effects of heavy metal discharge in a salmon river. Fish. Bd. Sweden, Inst. Freshwater Res., Drottningholm 55:91-131.

In the Ricklea River in northern Sweden, salmon Salmo salar and to a lesser extent, trout Salmo trutta popoulations have decreased since 1965, possibly due to pollution or failure of spawning. Simultaneously, there was a decrease in abundance of invertebrate fauna, especially winter nymphs of mayflies Baetis rhodani and Ephemerella mucronata, and backfly larvae. A diamond factory began operation in the upper river in 1963; nickel was used from 1963 to 67 and cobalt since 1967. Lime addition did not prevent metals from dissociating in the acidic river water. Heavy metal consumption and discharge has increased each year; a purification plant was installed in 1973. An electroplating plant was in operation from 1964 to 69. Decreases in Salmo populations and invertebrate fauna were synchronous with activities at the diamond factory. In 1972 and 73, cobalt water levels were highest in autumn and winter, at 10 to 43 ug/l. Surficial sediment concentrations of Co were 14 to 24 mg/kg below the discharge where Fontinalis moss accumulated 770 to 820 mg Co/kg dry wt in 1973. When 470 or 3950 ug/l cobalt nitrate was added to water, all Ephemerella nymphs living on their natural substrate (Fontinalis), died within 2 wks. Mortality was also high and subimagine emergence retarded in 32.6 ug Co/l. In 5.2 ug Co/l, weight of subimaginates decreased and development was slightly retarded.

2998. Speranza, A.W., R.J. Seeley, V.A. Seeley and A. Perlmutter. 1977. The effect of sublethal concentrations of zinc on reproduction in the zebrafish, Brachydanio rerio Hamilton-Buchanan. Environ. Pollution 12:217-222.

Adult zebrafish, when held in water containing a threshold concentration (5 mg/l) of zinc for a 9-day period during which the gametes were maturing, showed a delay in spawning. When spawning did occur, experimental pairs of fish produced an average of 165 eggs of which only 21% were viable. In contrast, controls produced an average of 434 eggs of which 90% were viable. In addition, survival of eggs to hatching was significantly lower in exposed groups than in controls, survival rate for the experimentals being 0.9%, vs. 63% in controls. Adverse effects of zinc on zebrafish can be reversed by returning the fish to a zinc-free environment.

2999. Stahl, S. 1978. Calcium uptake and survival of Bacillus stearothermophilus. Arch. Microbiol. 119:17-24.

Calcium transport in resting vegetative cells of B. stearothermophilus was studied by determining retention of Ca-45, in a membrane filter assay. Kinetics of death by vegetative cells suspended in buffer at 55 C was also investigated. Calcium influx required an energy source of glucose-1-phosphate and the system exhibited saturation kinetics. Bacteria accumulated 40.1 mg Ca/kg in one min in 240 mg Ca/l. Requirements for survival of thermophilic cells reflected those of the calcium transport system. Cells treated with nitrogen gas showed an increased thermal stability and a decreased efflux of calcium. The initial velocity of calcium influx correlated linearly with survival of cells after 1 min at 55 C. Lanthanum, and to a lesser extent manganese and strontium, inhibited calcium influx and reduced survival. Magnesium did not inhibit calcium influx, but could replace calcium as a stabilizing agent. Results suggest that the thermophilic cells are not intrinsically heat stable but survive due to a high cellular concentration of divalent ions.

3000. Stancyk, S.E. and P.L. Shaffer. 1977. The salinity tolerance of Ophiothrix angulata (Say) (Echinodermata:Ophiuroidea) in latitudinally separate populations. Jour. Exper. Marine Biol. Ecol. 29:35-43.

O. angulata from an estuary in South Carolina were less tolerant of reduced salinity than those from an estuary in Florida. Animals from North Inlet, South Carolina, became incapacitated more rapidly after exposure to a reduced salinity, and were less able to recover after return to normal salinity. This difference probably results from the more severe selection for salinity tolerance at Cedar Key, Florida. The Florida estuary has a lower average salinity (25 o/oo) than that in South Carolina (30 o/oo), and has more frequent extended periods of reduced salinity. The two populations are of different color varieties and size, and there may be differences in breeding seasons as well. The South Carolina and Florida populations of O. angulata may, therefore, represent different races.

3001. Sunda, W.G. and J.A.M. Lewis. 1978. Effect of complexation by natural organic ligands on the toxicity of copper to a unicellular alga, Monochrysis lutheri. Limnol. Oceanogr. 23:870-876.

The effect of copper on division rate of M. lutheri was tested in media with different concentrations of natural organic ligands from filtered river water. Increased binding of copper by natural ligands was associated with decreased toxicity of a given concentration of added $CuSO_4$. In 10% river water, algal cell division rate decreased from 1.5 doublings/day with 0.5 ug Cu/l to 0.09 doublings/day with 210 ug Cu/l. However, in 90% river water, division rate was 0.14 doublings/day in up to 635 ug Cu/l. The decrease in copper toxicity with increasing complexation could be explained quantitatively in terms of a dependency of toxicity on the concentration of free cupric ion. Sixty-one to 99% of total $CuSO_4$ added to river water was in the form of Cu-natural organic complexes. These results indicate that complexation of copper by organic ligands influences the toxicity of copper in natural waters by complexing with free cupric ions.

3002. Tagatz, M.E. and M. Tobia. 1978. Effect of barite ($BaSO_4$) on development of estuarine communities. Estuarine Coastal Marine Sci. 7:401-407.

Barite ($BaSO_4$), the primary component of oil drilling muds, affected the composition of estuarine communities developed from planktonic larvae in aquaria which contained sand and flowing estuarine water. Various experimental aquaria contained: sand only; a mixture by volume of 1 part barite and 10 parts sand; 1 part barite and 3 parts sand; or sand covered by 0.5 cm of barite. For all environments, annelids and molluscs were the numerically dominant phyla collected after 10 weeks exposure. A total of 59 species of annelids, crustaceans, coelenterates, echinoderms, molluscs, nemerteans, sipunculids, and tunicates were collected. Significantly fewer animals and species developed in aquaria with sand covered by barite than in aquaria unexposed or exposed to 1 barite:10 sand. Number of animals in aquaria containing 1 barite:3 sand also differed from control aquaria. Annelids were particularly affected and significantly fewer were found in all exposures than controls. Molluscs decreased markedly in number only in barite-covered aquaria. Barite, however, did not impede growth (as height) of the abundant clam, Laevicardium mortoni, or decrease abundance of other groups. It was concluded that large quantities of barite discharged during offshore oil drilling, may adversely affect colonization of benthic animals.

3003. Takeda, M., Y. Inamasu, T. Koshikawa, T. Ueda, M. Nakano, T. Tomida, and M. Hamada. 1976. On mercury and selenium contained in tuna fish tissues - II. total mercury level in muscles and viscera of yellowfin tuna. Jour. Shimonoseki Univ. Fish. 25:47-65. (In Japanese, English abstract).

Total mercury level and lipid content of 39 yellowfin tuna, Thunnus albacares, from the Middle Pacific, the West Pacific, and the East Indian Ocean were determined. Total mercury in dark muscle and abdominal muscle was correlated to that in dorsal muscle. Average levels in these tissues were almost the same at 0.21 to 0.25 mg Hg/kg wet wt. Stomach contained an average of 0.12 mg Hg/kg, liver contained 0.13, spleen 0.64, and kidney 0.33; contents of stomach averaged 0.06 and intestine 0.05. Mercury in muscle, liver, stomach, and intestine contents increased almost exponentially with body length. Relatively high Hg concentrations of 0.40 to 0.59 mg/kg wet wt in muscle, 0.45 in stomach, 0.50 in liver, 2.06 in spleen, and 0.53 in kidney were recorded in tuna caught off Brisbane, Australia, or Lombok, Indonesia. The major kinds of food species found in tuna stomach, in quantitative order, were squid, sardine, horse mackerel, and shrimp. Total mercury of each prey species was <0.1 mg/kg, except a sardine (0.17) and octopus (0.13) in a tuna from Lombok Island.

3004. Tevlin, M.P. 1978. An improved experimental medium for freshwater toxicity studies using *Daphnia magna*. Water Research 12:1027-1034.

Difficulties in formulating experimental media for use in toxicity studies are indicated, with particular reference to heavy metals and their possible chelation by agents in the media. Physiological responses by *Daphnia* with green alga, *Chlorella* sp., to sublethal cadmium poisoning were investigated. The synthetic media included labile Fe-EDTA complex as a source of soluble iron which is essential for growth of both *Daphnia* and *Chlorella*. Attention is drawn to the almost universal complexing ability of EDTA with metal ions, and to mechanisms whereby EDTA may be released from the Fe-EDTA complex under experimental conditions. Synthesis of a ferri-gluconate complex as an alternative source of soluble iron is described. This complex is theoretically more iron-specific than Fe-EDTA, while providing equally well for *Chlorella* growth and *Daphnia* growth and fecundity. Restriction of pH variation in the experimental medium, within its chemically stable range of 6.0-9.0, is difficult over 10 days. Most buffers with a suitable pK_a value ($\sim$7.5) were toxic or had some complexing ability. HEPES buffer at 0.001 M restricted pH variation to within 0.5 pH units without adversely affecting *Chlorella* growth or *Daphnia* growth and fecundity. Chemical estimation of cadmium-complexing by each iron source and each buffer was not possible since the presence of chelating agents imposes restrictions on the methods available, particularly at low cadmium concentrations. Instead, a 48-hr acute toxicity bioassay of the reduction of *Daphnia* due to cadmium in media containing each potential chelating agent was used. These data indicate that 0.001 M HEPES buffer does not complex cadmium at 0.1 mg/l, and that ferri-gluconate is less likely to do so than ferri-EDTA. In 1.0 mg Cd/l, addition of 0.001 M or 0.002 M HEPES did not improve *Daphnia* survival from 0%; with 0.002 M TES and 0.005 M TES, respectively, about 25% and 60% of the specimens survived. Survival in ferri-gluconate in 1.0 mg Cd/l was 30% and with ferri-EDTA 50%.

3005. Tucker, C.S. and C.E. Boyd. 1978. Consequences of periodic applications of copper sulfate and simazine for phytoplankton control in catfish ponds. Trans. Amer. Fish. Soc. 107:316-320.

Treatment of channel catfish, *Ictalurus punctatus*, production ponds with biweekly applications of 0.84 kg/hectare copper sulfate was ineffective in reducing phytoplankton density over 5 months. Three days after each addition, Cu pond levels were 10-18 ug/l; concentrations were 4.0-9.0 ug Cu/l after 10 days. Three periodic applications of simazine totaling 1.3 mg/l drastically reduced phytoplankton density. However, extended periods of low dissolved oxygen concentrations following simazine applications resulted in decreased fish yields and poor conversion ratios compared to control ponds. Catfish yield, in kg/hectare, was 2640 for controls, 2720 for Cu-treated, and 2100 for simazine-treated ponds.

3006. Voyer, R.A., C.E. Wentworth, Jr., E.P. Barry and R.J. Hennekey. 1977. Viability of embryos of the winter flounder Pseudopleuronectes americanus exposed to combinations of cadmium and salinity at selected temperatures. Marine Biology 44:117-124.

Developing eggs of winter flounder were exposed to 9 combinations of cadmium (range 0.1 to 2.1 mg Cd/l) and salinity (10, 20, 30 o/oo) at 5 and 10 C. Overall mean times to 50% hatch ranged from 7.7 days at 10 C, to 17.9 days at 5 C. Mean percentages of total hatches ranged from 50 to 100% for all treatment combinations. Percentages of viable hatches were generally lowest at 10 o/oo S and highest in the 25 to 30 o/oo S range. At both temperatures, cadmium significantly influenced viable hatch in all experiments. Viable hatch was also significantly influenced by salinity in both tests at 5 C and in 2 of 3 tests at 10 C. The interaction between cadmium and salinity also significantly affected viable hatch at 10 C.

3007. Waiwood, K.G. and F.W.H. Beamish. 1978. Effects of copper, pH and hardness on the critical swimming performances of rainbow trout (Salmo gairdneri Richardson). Water Research 12:611-619.

Critical swimming velocities of trout at 12 C were determined in different combinations of copper, pH and hardness after exposure for 0.5, 5.0, 10.0, and 30.0 days. When copper was not applied, hardness, pH and exposure time had no appreciable effect on critical performance. Copper had the greatest effect on swimming performance at 5 days of exposure at up to 200 ug Cu/l. At pH 7.5-8.0, recovery from the initial depression was complete after 10 days of exposure. However, critical swimming performance did not return to control levels in pH 6.0 treatments. For any given hardness, copper had a greater effect on critical speed at low pH. A given copper treatment had a more pronounced effect at low hardness. LC-20 (240 hrs) values ranged from 22 to 330 ug Cu/l between conditions of lowest hardness of 30 mg/l and pH 6, and highest hardness of 360 mg/l and pH 8. No distinction could be made among total, soluble, or extractable copper, but predicted concentrations of 6 specific cupric ions varied with pH and hardness. Of these copper species, only Cu^{2+} and $CuOH^{+}$ were significantly related to critical performance. In the presence of 25 or 40 ug Cu/l, maximum oxygen consumption decreased and energy expenditure for a given swimming speed increased.

3008. Weiss, A.A., S.D. Murphy, and S. Silver. 1977. Mercury and organomercurial resistances determined by plasmids in Staphylococcus aureus. Jour. Bacteriology 132:197-208.

Penicillinase plasmids of Staphylococcus aureus often contain genes conferring resistance to inorganic mercury (Hg^{2+}) and the organomercurial phenylmercury acetate. The mechanism of resistance was the enzymatic hydrolysis of phenylmercury to benzene plus inorganic ionic mercury, which was then enzymatically reduced to metallic mercury (Hg^{0}). The Hg^{0} was rapidly volatilized from the medium into the atmosphere. After the mercurial was degraded and the mercury was volatilized, the resistant cells were able to grow. These plasmids also conferred the ability to volatilize mercury from thimerosal, although the plasmid-bearing strains were equally as thimerosal sensitive as the S. aureus without plasmids. None of the plasmids conferred the ability to volatilize mercury from several other organomercurials. Although mercury was not volatilized from p-hydroxymercuribenzoate or fluoresceine mercuric acetate, the plasmid-bearing strains were resistant to these organomercurials. The ability to volatilize mercury from Hg^{2+} and phenylmercury was inducible. The range of inducers included Hg^{2+}, phenylmercury, and several organomercurials that were not substrates for the degradation system. Mercury-sensitive mutants have been isolated from the parental plasmids. Thirty-one such mercury-sensitive strains fall into three classes: 1) mercury-sensitive strains totally devoid of the phenylmercury hydrolase and Hg^{2+} reductase activites; 2) mutants with normal hydrolase levels and no detectable reductase; and 3) mutants with essentially normal hydrolase levels and low variable (5 to 25%) levels of reductase activites. The mercury-sensitive strains were also sensitive to phenylmercury, including those with the potential for hydrolase activity.

3009. Woodrow, G.C., L. Langman, I.G. Young, and F. Gibson. 1978. Mutations affecting the citrate-dependent iron uptake system in Escherichia coli. Jour. Bacteriology 133:1524-1526.

Isolation of six strains of E. coli carrying mutations affecting the citrate-dependent iron uptake system is described. Genetic analysis of these mutants showed that mutations affecting the citrate system are clustered together at one locus on the E. coli chromosome.

3010. Yamada, M., T. Koyama, and M. Matsuhashi. 1977. Interconversion of large packets and small groups of cells of Micrococcus rubens: dependence upon magnesium and phosphate. Jour. Bacteriology 129:1513-1517.

M. rubens, a gram-positive coccus, usually forms large cubic packets of more than 500 cells regularly arranged in three-dimensional cell groups. In medium with extremely low concentrations of Mg^{2+} and phosphate, in which the cells can only grow on an agar surface, M. rubens formed small groups of 2 to 20 cells. Irregularly arranged cell groups of intermediate size were obtained in culture media containing intermediate concentrations of Mg^{2+} and phosphate.

3011. Young, A.M. and T.L. Hazlett, III. 1978. The effect of salinity and temperature on the larval development of Clibanarius vittatus (Bosc) (Crustacea:Decapoda: Diogenidae). Jour. Exp. Marine Biol. Ecol. 34:131-141.

Hermit crab, C. vittatus, larvae were reared in 20 combinations of 4 salinities (15, 20, 25, and 30 o/oo) and 5 temperatures (15, 20, 25, 30, and 35 C). No development was observed in any salinity at 15 C, but partial development occurred in all other test conditions. Metamorphosis to juvenile crabs was noted only at salinities of 25 and 30 o/oo in combination with temperatures of 25 and 30 C. In general, development times were decreased at higher temperatures; no trend was evident for salinity.

3012. Young, M.L. 1977. The roles of food and direct uptake from water in the accumulation of zinc and iron in the tissues of the dogwhelk Nucella lapillus (L.). Jour. Exp. Marine Biol. Ecol. 30:315-325.

A description of zinc and iron accumulation in the tissues of Nucella lapillus, a predatory gastropod, has been obtained with the aid of seawater and barnacles, Balanus balanoides, labelled with Zn-65 and Fe-59. The food chain is the major source of Zn and Fe in tissues, input being approximately two orders of magnitude greater than that from seawater. Neither metal is accumulated up the food chain. The fractions of zinc and iron assimilated from food are similar, as are their rates of excretion from tissues of N. lapillus. The relative concentrations of zinc and iron in tissues reflect their relative concentrations in food. Results are discussed with reference to zinc and iron accumulation by the herbivorous winkle, Littorina littoralis.

3013. Aarkrog, A. 1977. Environmental behaviour of plutonium accidentally released at Thule, Greenland. Health Physics 32:271-284.

Plutonium contamination resulting from a B-52 airplane accident in 1968 at Thule, Greenland, was studied in 1968, 1970, and 1974. Contamination was confined mainly to the marine environment, where plutonium was preferentially accumulated in sediment and benthic fauna. Radioactive plutonium levels of sediments decreased with depth and distance from point of impact. Pu-239,240 in the marine environment from the accident was estimated at 25-30 Ci, and Pu-238 about 0.5 Ci. Surface sediment concentrations within 1 km of impact were 23,000 pCi/kg ash wt in 1968, 13,000 in 1970, and 17,000 in 1974. Benthic animals showed a horizontal distribution of radioactivity similar to sediment. From 1968 to 1970, Pu-239,240 concentrations in biota decreased by an order of magnitude; since 1970 the decrease has been less evident. Plutonium concentrations in worms within 1 km of the accident were 230,000 pCi/kg ash wt in 1968, 3.4 in 1970, and 5.7 in 1974. Seven species of bivalve molluscs within one km of the site contained 4600, 390, and 240 pCi/kg fresh wt, and brittlestars and seastars contained 380, 140, and 81 pCi/kg fresh wt in respective years. There were no indications of increased Pu in surface seawater or marine plants and zooplankton. Algae, Fucus and Laminaria, contained 2.0 to 19.0 pCi Pu-239,240/kg wet wt and shrimp contained 35 to 72 pCi/kg fresh wt during the three surveys. Vertebrates showed no tendencies to increase plutonium levels after the accident. Pu content in 6 species of fish ranged from 1.0 to 40.0 pCi/kg fresh wt in collections of 1968 to 1974, entrails of 2 species of birds contained 0.3 to 2.2, and entrails, liver, stomach, and intestine of 3 species of seals and walrus contained 0.5 to 1.0 pCi/kg.

3014. Babich, H. and G. Stotzky. 1978. Toxicity of zinc to fungi, bacteria, and coliphages: influence of chloride ions. Appl. Environ. Microbiology 36:906-914.

A 65.4 mg/l concentration of Zn^{2+}, as $ZnSO_4$, decreased survival of *Escherichia coli*, enhanced survival of *Bacillus cereus*, did not significantly affect survival of *Pseudomonas aeruginosa*, *Nocardia corallina*, and selected coliphages, completely inhibited mycelial growth of *Rhizoctonia solani*, and reduced mycelial growth of *Fusarium solani*, *Cunninghamella echinulata*, *Aspergillus niger*, and *Trichoderma viride*. Toxicity of zinc to fungi, bacteria, and coliphages was influenced by 0.5 and 1.0 M NaCl. Increased toxicity of zinc in the presence of high NaCl was not a result of a synergistic interaction between Zn^{2+} and elevated osmotic pressures, but of the formation of complex anionic Zn-Cl species that exerted greater toxicities than cationic Zn^{2+}. Conversely, decrease in zinc toxicity with increasing concentrations of NaCl probably reflected the decrease in levels of Zn^{2+} due to the formation of Zn-Cl species, which was less inhibitory to these microbes than Zn^{2+}. *A. niger* tolerated higher concentrations of zinc with NaCl at 37 C than 25 C.

3015. Berk, S.G., A.L. Mills, D.L. Hendricks, and R.R. Colwell. 1978. Effects of ingesting mercury-containing bacteria on mercury tolerance and growth rates of ciliates. Microbial Ecology 4:319-330.

A marine protozoan ciliate, *Uronema nigricans*, acquired tolerance to mercury within one generation after being fed mercury-laden bacteria, *Pseudomonas* sp., followed by exposure of these ciliates to various concentrations of mercury (10 to 100 ug/l) in solution. After 14.5 hours in 10 ug Hg/l, 26% of ciliates fed Hg-free bacteria died, compared to 8.4% of those fed Hg-laden bacteria. Ciliates fed Hg-free bacteria and subsequently exposed to increasing levels of mercury in solution showed an elevated tolerance to concentrations which, on initial testing, resulted in mortality of 83% of the ciliate population. Ingestion of mercury-laden bacteria had no effect on growth rates of ciliates that had been fed Hg-laden and Hg-free bacteria, based on measurements at 3 and 14 days.

3016. Briand, F., R. Trucco, and S. Ramamoorthy. 1978. Correlations between specific algae and heavy metal binding in lakes. Jour. Fish. Res. Bd. Canada 35:1482-1485.

Four-month experiments conducted at Heney Lake, Quebec, in summer 1976, showed the binding capacity for Cu^{2+}, Hg^{2+}, Pb^{2+}, and Cd^{2+} to be related to algal species composition rather than to total algal biomass or to physicochemical parameters. Most of the metal binding could be accounted for by certain species of green algae, diatoms, and chrysomonads that usually constituted only a minor fraction of total algal volume.

3017. Brown, B.E. 1978. Lead detoxification by a copper-tolerant isopod. Nature 276:388-390.

Copper and lead uptake was studied in two populations of isopods, Asellus meridans: one Cu and Pb tolerant group from Hayle River, with Cu water levels between 0.10 and 0.25 mg/l and Pb <0.01 mg/l, and one Pb tolerant but not Cu tolerant group from Gannel River, with Pb water levels of 0.19 to 0.35 mg/l and Cu of 0.01 to 0.04 mg/l. After exposure for 14 days to constant copper (0.25 mg/l) and increasing lead concentrations (0.0 to 0.4 mg/l), isopods from the Hayle showed decreasing Cu body levels, from 3500 to 1500 mg/kg dry wt and increasing Pb from 500 to 4500 mg/kg, while isopods from Gannel had slight changes, from 800 to 400 mg Cu/kg dry wt and from 1800 to 3000 mg Pb/kg. With constant lead (0.25 mg/l) and increasing copper (0.0 to 0.4 mg/l), Hayle isopods decreased body Pb from 2500 to 1500 mg/kg dry wt and increased Cu from 2500 to 4000 mg/kg. Gannel isopods body levels varied from 2000 to 2500 mg Pb/kg regardless of increasing Cu, and increased from 1200 to 2000 mg Cu/kg dry wt. Hayle populations of isopods accumulated more Cu and Pb and were able to "detoxify" lead by storing the metal in cuprosomes in the hepatopancreas at the expense of copper. Cu and Pb appeared to compete for the same sites in the hepatopancreas.

3018. Brown, D.A., C.A. Bawden, K.W. Chatel, and T.R. Parsons. 1977. The wildlife community of Iona Island jetty, Vancouver, B.C., and heavy-metal pollution effects. Environmental Conservation 4:213-216.

Marine and terrestrial organisms (algae and higher plants, bivalve molluscs, crabs, ducks and raptorial birds, and rats) abundant in a community associated with a marine sewer outfall from Vancouver, B.C., are contaminated with high levels of heavy metals, but are apparently protected from their toxic effects by production of metallothionein protein. Amount of metallothionein and heavy metal loading appears to depend primarily on degree of pollution and secondly on species of animal and its position in the food web. As total quantity of cadmium, copper, and zinc in animal tissue increased from 0.1 to 0.4 mmole metals/kg, ratio of metals on metallothionein to enzyme protein fractions rose from 0.25 (bivalves *Mytilus edulis*, *Macoma inconspicua*, and *Cryptomya californica*) to 0.40 (rats *Rattus norvegicus*) to 0.45 (mussels closer to outfall) to 0.70 (ducks).

3019. Carlsson, S. 1978. A model for the movement and loss of ^{137}Cs in a small watershed. Health Physics 34:33-37.

The mathematical model describing turnover of fallout Cs-137 in a small lake is based on the assumption that water receives Cs-137 from deposition on the lake surface and from removal from the drainage-area. Loss of Cs-137 from lake water is assumed to occur through outflow and sedimentation. Based on observed concentrations of Cs-137 in water and sediment, the model determined that 1.9% of freshly deposited Cs-137 and 0.56% per year of the accumulated Cs-137 in the drainage-area is transported to the lake and that 38% of Cs-137 is accumulated in lake sediment. This indicates that the radionuclide is strongly bound to soil and vegetation in the drainage-area and that movement of Cs-137 in the watershed is small and mainly consists of a transport to sediment. Loss of Cs-137 from the watershed is small; the dominant pathway is through physical decay.

3020. Carlsson, S. 1978. A model for the turnover of ^{137}Cs and potassium in pike (*Esox lucius*). Health Physics 35:549-554.

A mathematical model for turnover of cesium-137 and potassium in pike is described. It is assumed that the change in body burden of the elements is the difference between intake and excretion, which in turn are functions of metabolic rate. The model, quantitatively based on existing data on food (other fish) of pike and its concentrations of Cs-137 and K, has been applied to calculate biological half-times in pike from Lake Ulkesjon, Sweden. Turnover was estimated as 1.3 yr for Cs and 0.55 yr for K, for a pike weighing 500 g at a water temperature of 8-10 C. Half-times were longer in larger pike. Maximum whole-body Cs-137 concentrations measured between 1961 and 1973 were 8.5 nCi/kg in pike and 5.0 nCi/kg in their prey. Influences of various assumptions about intake and elimination of Cs-137 and K on these calculations are discussed.

3021. Chapman, G.A. 1978. Effects of continuous zinc exposure on sockeye salmon during adult-to-smolt freshwater residency. Trans. Amer. Fish. Soc. 107:828-836.

Adults of sockeye salmon, Oncorhynchus nerka, were chronically exposed to zinc for 3 months then spawned. The resultant embryonic through smolt stages were also subjected to various concentrations of zinc for 18 months. Zinc concentrations were 30 to 112 ug/l during adult-to-smolt exposure period, and an additional 242 ug/l for embryo-to-smolt expsoure. No adverse effects were observed, on survival, fertility, fecundity, growth, or on subsequent survival of smolts transferred to seawater. Fertility was above 97% in adults exposed to up to 120 ug Zn/l. Survival was >90% in all but 3 cases for adults, eggs, and juveniles in up to 242 ug Zn/l. Acclimatization to 242 ug Zn/l markedly decreased mortality at Zn levels that were lethal to unacclimated salmon juveniles. The 112- and 242-ug/l concentrations were 0.15 and 0.32, respectively, of the 749 ug/l, LC-50 (96-hr) value for 8-month-old sockeye salmon. An application factor relating LC-50 (96 hr) and "safe" concentrations of zinc to anadromous sockeye salmon in soft water appears to be >0.15, at least 15X larger than the often recommended 0.01 application factor for zinc based on studies with other species.

3022. Chapman, G.A. 1978. Toxicities of cadmium, copper, and zinc to four juvenile stages of chinook salmon and steelhead. Trans. Amer. Fish. Soc. 107:841-847.

Continuous-flow toxicity tests were conducted to determine relative tolerances of newly hatched alevins, swim-up alevins, parr, and smolts of chinook salmon, Oncorhynchus tshawytscha, and steelhead, Salmo gairdneri, to cadmium, copper, and zinc. Newly hatched alevins were much more tolerant to cadmium, and to a lesser extent zinc, than later juvenile forms. However, developmental progression from swim-up alevin, through parr, to smolt was accompanied by a slight increase in metal tolerance. LC-50 (96 hr) values for all 4 life stages ranged from 1.0 (steelhead parr) to >27 ug Cd/l (steelhead alevins); 17 (steelhead swim-up) to 38 ug Cu/l (salmon parr); and 93 (steelhead parr) to 815 ug Zn/l (steelhead alevins). LC-50 (200 hr) values ranged for all groups from 0.9 to >27 ug Cd/l, 15 to 30 ug Cu/l, and 93 to >661 ug Zn/l. Steelhead were consistently more sensitive to Cd, Cu and Zn than chinook salmon. The author suggests that when a sensitive life stage for acute toxicity tests with metals is sought, the more resistant newly hatched alevins should be avoided. Although tolerance may increase with age, all late juvenile life stages are more sensitive than newly-hatched alevins and should give replicable results.

3023. Chapman, G.A. and D.G. Stevens. 1978. Acutely lethal levels of cadmium, copper, and zinc to adult male coho salmon and steelhead. Trans. Amer. Fish. Soc. 107:837-840.

Flow-through acute toxicity tests of cadmium, copper, and zinc were conducted with adult male coho salmon, *Oncorynchus kisutch* and adult male steelhead, *Salmo gairdneri*. LC-50 (96 hr) values for copper were 46 ug/l for salmon and 57 ug/l for steelhead. LC-50 (96 hr) values for zinc were 905 and 1755 ug/l for salmon and steelhead, respectively. Mortality induced by cadmium was slow at onset, but 50% mortality occurred after more than a week at 3.7 ug/l for salmon and 5.2 ug/l for steelhead. Hardness and alkalinity of water supply were higher during tests with steelhead, complicating direct comparisons between the two species.

3024. Chin, B., G.S. Lesowitz, and I.A. Bernstein. 1978. A cellular model for studying accommodation to environmental stressors: protection and potentiation by cadmium and other metals. Environmental Research 16:432-442.

Exposure of bacteria, *Physarum polycephalum*, to low concentrations of cadmium insufficient to delay mitosis, elicited a protective response against a mitotic delay resulting from subsequent exposure to higher Cd concentrations. The concentration of Cd^{2+} in the subthreshold challenge could be lowered to 10^{-5} M (about 1.12 mg/l) and maintain complete protection against a suprathreshold exposure of 5 x 10^{-4} M Cd^{2+}. A subthreshold challenge of 10^{-4} M provided full protection against 7 x 10^{-4} M Cd^{2+}. A subthreshold challenge of 10^{-4} M Cd^{2+} could be placed anywhere in the cell cycle approaching but not abutting a suprathreshold challenge of 5 x 10^{-4} M Cd^{2+} in late G_2 stage and still provide complete protection with the exception of one point in early S stage. At that point, 10^{-4} M Cd^{2+} was toxic to the cell; however, partial protection developed. Other responses developed when other metals were substituted for cadmium. Cd^{2+} protected against exposure to Hg^{2+} and Ni^{2+}, but potentiated exposures to Co^{2+}, Cu^{2+}, Pb^{2+}, or Zn^{2+}. Exposure to Hg^{2+} and Ni^{2+} protected bacteria against Cd^{2+} (as well as Hg^{2+} and Ni^{2+}), while exposure to Co^{2+}, Pb^{2+}, or Zn^{2+} potentiated toxicity of Cd^{2+}.

3025. Coughtrey, P.J. and M.H. Martin. 1978. Cadmium uptake and distribution in tolerant and non-tolerant populations of Holcus lanatus grown in solution culture. Oikos 30:555-560.

Cadmium uptake and distribution between roots and shoots of a tolerant and a non-tolerant population of plant, Holcus lanatus, grown in culture solution were studied with reference to both concentration and total cadmium content. Mean concentrations, in mg Cd/kg dry wt, after 7 days in 1.0 mg Cd/l were: in non-tolerant plants, 145 in shoots, 1211 in roots, and 545 in whole plants; in tolerant plants, 43 shoots, 1799 roots, and 538 whole plants. When exposed to 2.0 mg Cd/l, non-tolerant plants contained 191, 2229, and 1099 mg/kg, respectively, and tolerant plants contained 89, 2349, and 738. In normal non-tolerant plants, as much as 90% of whole plant Cd remains in roots. In tolerant plants translocation of Cd to shoots is reduced with a concomitant increase of cadmium concentration in roots. Translocation differences are shown to be related to differences in biomass and rates of metal uptake between tolerant and non-tolerant populations.

3026. Davis, J.A. and C.E. Boyd. 1978. Concentrations of selected elements and ash in bluegill (Lepomis macrochirus) and certain other freshwater fish. Trans. Amer. Fish. Soc. 107:862-867.

Bluegills and 16 other species of freshwater fish collected from southeastern U.S. were found to differ in concentrations of calcium, magnesium, potassium, sodium, nitrogen, phosphorus, sulfur, and ash depending upon species, size, and collecting site. Mean elemental concentrations, as percent dry wt, in bluegill from 24 ponds were: 5.65 for Ca, 1.20 for K, 0.42 for Na, and 0.19 for Mg. Range of concentrations in all species of fish collected from West Point Reservoir, Georgia, were: 2.36 to 10.30% dry wt for Ca, 0.91 to 1.30 for K, 0.26 to 0.62 for Na, and 0.13 to 0.23 for Mg. Authors conclude that elemental composition of fish fauna in a body of water is a function of species and size.

3027. Delhaye, W. and D. Cornet. 1975. Contribution to the study of the effect of copper on Mytilus edulis during reproductive period. Comp. Biochem. Physiol. 50A:511-518.

Mortality, respiration, and copper accumulation in mussels are exponential functions of the initial copper concentration with a critical value between 0.3 and 1.0 mg Cu^{2+}/1. An acceleration of mortality occurs during the reproductive period. Respiration is similarly affected. Oxygen consumption rates obtained at different copper concentrations show that more than one mechanism is disrupted. Most of the copper accumulated is bound to organic molecules. Cu accumulation is comparatively high in gills, mantle and foot. After 48 hrs, copper levels decreased in all organs, with no major organ respository observed. Critical concentrations seem to exist which inhibit some mechanisms; higher Cu concentrations have no markedly greater effects. The spawning period corresponds with an acceleration of copper uptake and consequently the critical concentration is reached more rapidly. The final result of these studies seems to be that the increase in copper toxicity during reproductive period is primarily attributable to a seasonal increase in mussel metabolism, engendering faster absorption of Cu, rather than a real increase of sensitivity.

3028. Deshimaru, O., K. Kuroki, S. Sakamoto, and Y. Yone. 1978. Absorption of labelled calcium-^{45}Ca by prawn from sea water. Bull. Japan. Soc. Sci. Fish. 44:975-977.

Absorption of labelled calcium from surrounding seawater by prawns, Penaeus japonicus, fed a diet without supplemental calcium was compared to that of prawns fed diets supplemented with calcium. Prawns were fed each diet in ordinary seawater, then one hour after the final feeding, transferred to seawater with Ca-45 $CaCl_2$. Prawns not fed supplemental calcium exhibited faster absorption and higher activity of Ca-45 over 23 hours than those fed calcium. Calcium content was 830 mg/kg in prawns not fed Ca and 710 mg/kg in those fed Ca.

3029. De Wolf, P. 1975. Mercury content of mussels from West European coasts. Marine Poll. Bull. 6:61-63.

Mytilus edulis and M. galloprovincialis were collected from the east side of the North Sea from Arcachon in France to Cape Skagen in Denmark and on the west side from Lands End in England to Edinburgh, Scotland. Mercury content, in mg/kg wet wt soft parts, of intertidal mussels ranged from 0.053 to 0.830 and varied with season of year. Values were high at all sampling stations in March and diminished until September, after which they increased again until March. The rapid decrease in Hg content from March to May is attributed to spawning, part of the Hg leaving with the gametes. In general, subtidal mussels contained less Hg than mussels collected from the intertidal zone. Highest Hg levels occurred in mussels taken from the vicinity of the Rhine and Eems Dollard and may reflect environmental contamination. Mercury values on the British coast were generally higher than values from the east side of the North Sea.

3030. Domby, A.H., D. Paine, and R.W. McFarlane. 1977. Radiocesium dynamics in herons inhabiting a contaminated reservoir system. Health Physics 33:523-532.

Blue heron, Florida caerulea, and green heron, Butorides virescens, nest at a radionuclide-contaminated reservoir on the Savannah River Plant site near Aiken, South Carolina. Green herons distributed their nests singly along the periphery of the reservoir but fed their nestlings exclusively upon amphibians from adjacent uncontaminated Carolina bays. Radiocesium burdens in green heron nestlings did not exceed 5.0 nCi/kg wet wt; 12 regurgitated food pellets averaged 0.2 nCi/kg. Twelve pairs of blue herons established a heronry upon a small island and fed their nestlings fish and amphibians foraged from within the radionuclide-contaminated reservoir system. Recently-hatched birds within the same nest did not exhibit significant differences in body burdens; maximum radiocesium burden determined was 27.4 nCi/kg wet wt. Substantial differences were found between nestlings from different nests. Radiocesium level of 43 regurgitated food pellets had a high correlation with observed levels in nestlings. Variation in food contamination is believed to be the major factor in observed variation between blue and green heron nestlings. Radiocesium levels in bluegill fish, Lepomis macrochirus, ranged from 2.3 to 52.3 nCi/kg wet wt, with highest values occurring nearest to the original Cs source. Variable contamination of primary prey species was correlated with differentially contaminated foraging sites, and indicates that adult blue herons tend to spatially partition available foraging areas.

3031. Establier, R., M. Gutierrez and A. Arias. 1978. Accumulation and histopathological effects of organic and inorganic mercury to the lisa (Mugil auratus Risso). Investigacion Pesquera 42:65-80. (In Spanish, English summary).

Inorganic ($HgCl_2$) and organic (CH_3HgCl) mercury uptake in flesh, blood, liver, kidney, spleen, intestine, pyloric caeca, and gills by M. auratus exposed to 0.1 mg/l $HgCl_2$ in seawater for 57 days and 0.008 mg/l CH_3HgCl for 45 days was determined. Fish in natural seawater contained concentrations of 0.47 mg total Hg/kg (presumably dry wt) in dorsal muscle and 0.92 in intestine. After 57 days in 0.1 mg Hg/l, levels were 10.3 mg/kg in muscle and 93.3 in intestine, and after 45 days in 0.008 mg Hg/l, 11.8 mg/kg in muscle and 41.8 in intestine. Histopathological effects of inorganic Hg on liver and intestine and organic Hg on gills, stomach muscle, liver, kidney, and intestine were also investigated.

3032. Eyman, L.D. and T.R. Trabalka. 1977. Plutonium-237: comparative uptake in chelated and non-chelated form by channel catfish (Ictalurus punctatus). Health Physics 32:475-478.

Chelation can either enhance or reduce uptake of ingested plutonium relative to PuOH (monomer) in channel catfish. Uptake was 10.5% in Pu-237 citrate, 6.2% in Pu-237 hydroxide, and 1.6% in Pu-237 fulvate. Biological half-lives for respective compounds were 30, 13, and 24 days. Reduced uptake of Pu-237 fulvate was due either to molecular weight of the complex or its stability in metabolic systems. Increased uptake of Pu-237 citrate was attributable to instability of the complex in metabolic systems.

3033. Frank, R., M.V.H. Holdrinet, R.L. Desjardine, and D.P. Dodge. 1978. Organochlorine and mercury residues in fish from Lake Simcoe, Ontario 1970-76. Environ. Biol. Fish 3:275-285.

Lake Simcoe in the central Ontario plain has four major streams draining the watershed. Persistent organochlorine insecticides were used in the basin for mosquito control and agricultural production until restricted: methylmercury compounds have been phased out and a voluntary restriction was imposed for polychlorinated biphenyls. Ten species of fish (Perca flavescens, Ambloplites rupestris, Micropterus dolomieui, M. salmoides, Catostomus commersoni, Stizostedion vitreum vitreum, Esox lucius, Lota lota, Salvenius namaycush, and Coregonus clupeaformis) were collected between 1970 and 1976 for organochlorine and mercury analysis. Mercury residues showed no change from 1970 to

1975-76 in five species; residues declined in two species, and increased in small specimens of *S. v. vitreum* from 0.20 to 0.25 mg/kg wet wt. Mercury residues, in mg/kg, in 1970 ranged from 0.01-0.04 in small *C. clupeaformis*, *C. commersoni*, and *A. ruprestris* to 0.32-0.48 in large *L. lota* and *M. dolomieui*. In 1975-76, concentrations ranged from 0.01-0.04 mg/kg in large and small *C. clupeaformis*, and small *M. dolomieui* and *C. commersoni* to 0.49-0.73 in large *S. namaycush*, *L. lota*, and *S. v. vitreum*. Among tissues analyzed, *L. lota* in 1971 contained 0.39 mg Hg/kg in liver and 0.22 in other tissues, eggs of *S. namaycush* in 1975-76 contained 0.09-0.12 mg Hg/kg. Correlations were observed between lipid content of fish and organic contamination, but not mercury residues.

3034. Fujita, M., K. Iwaskai, and E. Takabatake. 1977. Intracellular distribution of mercury in freshwater diatom, *Synedra* cells. Environmental Research 14:1-13.

Intracellular distribution of mercury in *Synedra* cells was investigated by measuring amounts of radioactive Hg incorporated into various subcellular components. Mercury initially accumulated in the chloroplast fraction and then translocated to the soluble fraction. Mercury levels reached 8000 cpm/l of cell culture in one fraction after 22 hr exposure (100 cpm = 0.6 ng Hg). When dead cells were used, no Hg accumulation was observed in any fraction.

3035. Guary, J.-C. and S.W. Fowler. 1978. Uptake from water and tissue distribution of neptunium-237 in crabs, shrimp and mussels. Marine Poll. Bull. 9:331-334.

Uptake of Np-237 was monitored in tissues of mussel *Mytilus galloprovincialis*, shrimp *Lysmata seticaudata*, and crab *Cancer pagurus*, exposed to the actinide in seawater under controlled conditions. Bioaccumulation was observed in all tissues examined, with highest concentration factors found in external shells of the three species. Concentration factors of Np-237 levels in exoskeleton or shell over water were 60 in crabs after 50 days, 15 in shrimp after 50 days, and 20 in mussels after 60 days. Muscle tissue of each organism had CF's of 1.0, 0.25, and 2.0, respectively. Despite some incorporation of Np-237 into internal tissues, 92-98% of the organisms' total Np-237 content was associated with non-edible shell or exoskeleton. Authors concluded that neptunium accumulation patterns in invertebrate tissues are very similar to those of plutonium.

3036. Gutierrez, M., R. Establier and A. Arias. 1978. Uptake and histopathological effects of cadmium and mercury to the sapo (Halobatrachus didactylus). Investigacion Pesquera 42:141-154. (In Spanish, English summary).

Accumulation of cadmium in flesh, blood, liver, kidney, and intestine of the marine teleost H. didactylus exposed to 50 mg Cd/l in seawater for 4 days, and accumulation of mercury in flesh and liver in fish exposed to 0.1 mg Hg/l for 49 days was determined. Cadmium concentrations in fish from natural seawater were 0.2 mg/kg dry wt in dorsal muscle and 1.5 in intestine. After 4 days exposure to 50 mg/l Cd, levels were 0.7 mg/kg in muscle and 289.9 in intestine. Cytohematological and histopathological effects of Cd and Hg on blood, liver, kidney, and intestine were also investigated.

3037. Hartung, R. 1973. Biological effects of heavy metal pollutants in water. In: Dhar, S.K. (ed.). Metal ions in biological systems. Studies of some biochemical and environmental problems. Advances Exper. Medicine Biology 40:161-172.

A brief review is presented of effects of cadmium, chromium, copper, lead, mercury, and zinc to freshwater species of algae and higher plants, crustaceans, molluscs, fish, waterfowl and fish-eating birds, and mammals. The author points out difficulties in evaluating heavy metal effects to aquatic organisms, including the resolution of chemical and physiological conditions during exposure, correctly predicting absorbed dose and effects, and the need to study subtle effects of growth, reproduction, and behavior.

3038. Hess, C.T., C.W. Smith, and A.H. Price. 1977. A mathematical model of the accumulation of radionuclides by oysters (C. virginica) aquacultured in the effluent of a nuclear power reactor to include major biological parameters. Health Physics 33:121-130.

Uptake, accumulation, and loss of radionuclides by Crassostrea virginica in the effluent of a nuclear power reactor was measured monthly for 3 years at four field stations in the Montsweag Estuary of the Sheepscot River and at a control station in nearby Damariscotta River Estuary, Maine. A mathematical model for time variation of the specific activity of oysters was developed to include physical and biological half-lives of various radionuclides, water temperature (oyster hibernation), and shell growth. The equation is driven by the liquid radionuclide effluent release schedule of Maine Yankee Nuclear Reactor. Comparison of monthly measurements of labelled cobalt, manganese, and cesium in oysters with model calculations show close agreement over all ranges of variation observed. Maximum radionuclide levels in oysters measured between 1973 and 1976 were 850 pCi/kg for Co-58, 135 for Co-60, 130 for Mn-54, 50 for Cs-134, and 100 for Cs-137. Biological half-lives, in days, were 35 for Co-58 and -60, 1500 for Mn-54, and 250 for Cs-134 and -137.

3039. Hidu, H. and H.H. Haskin. 1978. Swimming speeds of oyster larvae Crassostrea virginica in different salinities and temperatures. Estuaries 1:252-255.

Swimming speeds of oyster larvae, C. virginica, were determined in constant and increasing salinities. Normal non-directed swimming speeds in 25 o/oo S ranged from <1 cm/min for early veligers to 5 cm/min for eyed veligers. Temperature was an important variable. When subjected to hourly salinity increases of 0.5 o/oo, most larvae swam upward or downward at approximately 3X normal speeds. Larvae, with valves closed in response to traces of formalin, sank at speeds of 5 to 50 cm/min, depending on larval stage, regardless of salinity of 15, 20, or 25 o/oo.

3040. Holden, A.V. 1973. International cooperative study of organochlorine and mercury residues in wildlife, 1969-71. Pesticides Monitoring Jour. 7:37-52.

A two-part collaborative study of organochlorine pesticides, polychlorinated biphenyls (PCB's), and mercury residues was conducted by 26 laboratories in 12 countries. The first part involved analysis of 3 test samples containing organochlorine residues and one group containing mercury. Freeze-dried homogenates of muscle of pike, Esox lucius, contained mean values, in mg/kg, of 0.152 methylmercury and 0.165 total mercury before Hg-spiked solutions were added. Samples and analyses of several species of wildlife from both terrestrial and aquatic environments were also taken from areas considered free of pesticide usage and from areas seriously polluted. Results demonstrated difficulties in selecting species appropriate for international monitoring programs, in identifying areas of high contamination before analysis, and in relating concentrations to measurable biological effects. Mercury levels, in mg/kg, in marine mussels, *Mytilus edulis*, from 10 countries ranged from 0.03 to 0.23 in unpolluted areas, 0.08 to 0.31 in slightly polluted areas, and 0.02 to 0.46 in polluted areas. Concentrations in marine herring, *Clupea harengus*, (and freshwater pike) from 8 countries were <0.01 to 0.12 (0.27 to 0.68) unpolluted, 0.05 to 0.19 (0.08 to 2.12) slightly polluted, and <0.01 to 0.07 (0.65 to 3.85) polluted. Freshwater eel, *Anguilla vulgaris*, from 2 countries contained 0.24 to 0.35 unpolluted and 0.22 to 0.72 mg/kg polluted. Mercury concentrations in eggs from 6 species of aquatic birds, (eider *Somateria mollissima*, pelican *Pelicanus occidentalis carolinensis*, terns *Thalasseus maximus*, *Sterna hirundo*, and *S. sandvicensis*) from 6 countries were 0.33 mg/kg freeze-dried homogenate from unpolluted areas, 0.12 from slightly polluted areas, and 0.50 to 0.87 from polluted areas.

3041. Huckabee, J.W., S.A. Janzen, B.G. Blaylock, Y. Talmi, and J.J. Beauchamp. 1978. Methylated mercury in brook trout (*Salvelinus fontinalis*): absence of an *in vivo* methylating process. Trans. Amer. Fish. Soc. 107:848-852.

The possibility of *in vivo* conversion of inorganic mercury to methylated mercury (MeHg) in trout was tested by chronically exposing fish to 1.0 ug/l mercury, as $Hg(NO_3)_2$, for 56 days, and then maintaining them at background levels for 294 days. Inorganic mercury levels in test fish increased rapidly during exposure, reaching, at 116 days, 0.49 mg/kg wet wt in muscle, 11.3 in liver, 9.0 in gills, and 3.5 in intestine. MeHg concentrations in both control and test fish increased slowly at the same rate. Final 350-day concentrations, in mg/kg wet wt, were 0.04 in muscle, 0.03 in liver, 0.02 in gills, and 0.01 in intestine. These values were comparable to those found in wild brook trout from an uncontaminated area. This information indicates that fish do not methylate inorganic mercury *in vivo*, and that approximately one-half of the MeHg body burdens was acquired via food.

3042. Huisman, J. and J.H.G.T. Hoopen. 1978. A mercury buffer for toxicity experiments with green algae. Water, Air, Soil Poll. 10:325-333.

Mercury toxicity experiments with green algae are complicated by the fast reduction and evaporation of Hg. A Hg buffer system is described, which considerably stabilizes the Hg^{2+} concentration in test solutions. The Hg buffer consists of mercuric chloride and N-methyliminodiacetic acid (MIDA). Dissociation of Hg-MIDA complex compensates for loss of some mercury; however, 50% of experimental Hg was lost over 3 days in spite of MIDA addition. Green alga, Scenedesmus acutus, exposed to Hg^{2+} concentrations between 0.02 and 2.0 mg/l at 15 to 30 C showed no change in algal density during the first day of addition of Hg-MIDA, but generation time (measured by density) increased from 17 to 180 hrs. Different initial algal concentrations had similar results. In unbuffered medium, Hg was no longer in solution after 1 day, and algae lost Hg adsorbed onto cell walls by 2 days. With low initial algal concentrations, growth was inhibited initially, but resumed 2 days after Hg disappearance. Growth was not affected with a large initial algal concentration. No effect of MIDA on growth of algae was detected.

3043. Jackson, T.A. 1978. The biogeochemistry of heavy metals in polluted lakes and streams at Flin Flon, Canada, and a proposed method for limiting heavy-metal pollution of natural waters. Environ. Geology 2:173-189.

The biogeochemistry of Zn, Cd, Cu, Hg, and Fe in lakes and streams polluted by mine and smelter wastes emitted at Flin Flon, Canada, was investigated. In Schist Lake, a repository for both tailings-pond drainage and sewage, green algal blooms generated by nutrients from sewage promote entrapment of metals in sediments by: 1) accumulation of metals from solution by algal seston, with preferential uptake of Zn, the most abundant metal, followed by sinking of seston; and 2) production of H_2S during decomposition of dead algae, resulting in sulfide precipitation. Metals are partially resolubilized from seston as it decomposes while sinking. Preferential retention of Cu by sinking seston and by mud promotes Cu enrichment in mud, but the Cu/Zn ratio of mud varies with the Cu/Zn ratio of surface water seston. In bottom muds, partitioning of a metal between sulfide and organic matter is strongly dependent on the stability of the metal sulfide, the proportion of sulfide-bound metal decreasing in the order of Hg>Cd>Cu>Fe>Zn. Sulfide was much more effective than organic matter in suppressing remobilization of metals from bottom sediments. Authors concluded that introduction of sewage together with heavy-metal effluents into settling ponds could be an effective and economic method for limiting heavy-metal pollution of natural waters.

3044. Jorgensen, K.F., and K. Jensen. 1977. Effect of copper (II) chloride on the hatching rate of Artemia salina

(L.). Chemosphere 6:287-291.

Average hatching rates of *Artemia* eggs exposed to copper chloride, as fractions of control rate, were 0.79 in 0.001 mg Cu^{2+}/l, 0.55 in 0.01 mg/l, 0.27 in 0.1 mg/l, and 0.03 or lower in 1.0 mg/l or greater. Medium hatching rate in 48 hrs was observed at 0.014 mg Cu^{2+}/l. Minimum effect level for Cu was below 0.001 mg/l.

3045. Khandekar, R.N. 1977. Polonium-210 in Bombay diet. Health Physics 33:148-150.

Polonium-210 concentrations in foodstuffs in Bombay, India, were assessed to estimate Po-210 intake by man. Local fish contained 4.25 pCi/kg, which was relatively high compared to cereal, vegetables, and milk products. Drinking water contained 0.05 pCi/l. Food items accounted for a daily intake of 1.40 pCi Po-210 in humans. Water and air accounted for intakes of 0.15 and 0.07 pCi, respectively. Polonium reaching blood was 0.084, 0.009, and 0.019 pCi Po-210/day from food, water and air.

3046. Kilham, S.S., C.L. Kott, and D. Tilman. 1977. Phosphate and silicate kinetics for the Lake Michigan diatom *Diatoma elongatum*. Jour. Great Lakes Res., Internat. Assn. Great Lakes Res. 3:93-99.

Growth rates and uptake rates by a clone of freshwater *Diatoma elongatum* isolated from Lake Michigan were measured under silicate and phosphate limitation. Under silicate limited conditions, the half saturation constant for growth, K, was 1.51 uM SiO_2-Si, and maximum growth rate was 1.2 doublings/day. Results agreed with steady state kinetic information obtained for a two-step (uptake and utilization) growth model. Authors observed a dependence of the coefficient of luxury consumption on steady state growth rate. *D. elongatum* can store up to 28X more phosphate, and up to 4.4X more silicate than needed.

3047. Lorch, D.W. 1978. Desmids and heavy metals II. manganese: uptake and influence on growth and morphogenesis of selected species. Arch. Hydrobiol. 84:166-179.

Effect of manganese was investigated on cell morphology of 5 species of Desmidiaceae algae, *Closterium ehrenbergii*, *Gonatozygon aculeatum*, *Micrasterias rotata*, *Netrium digitus*, and *Penium spirostrilatum*. In 7.0 mg Mn/l, yield was reduced in 4 species, down to 19% and 33% for *Netrium* and *Micrasterias*, respectively, and was increased to 141% for *Penium*. Manganese accumulation followed saturation kinetics, with saturation levels of 2000 to 12,550 mg/kg, except *Closterium* which did not reach saturation at the highest level tested of 7.0 mg Mn/l. Uptake at saturation level of the 4 species was 1.5 to 5.1% of available manganese. Mn uptake by isolated cell walls reached saturation levels of 18% of intact cells for *Micrasterias*, 90% for *Closterium*, and 184 to 504% for the other 3 species.

3048. Macka, W., H. Wihlidal, G. Stehlik, J. Washuttl, and E. Bancher. 1978. Metabolic studies of Hg-203 on *Chlamydomonas reinhardi*. Experientia 34:602-604.

Sterile cultures of algae, *Chlamydomonas reinhardi*, were treated with Hg-203 at 25 C to identify possible formation of volatile mercury compounds. Experiments were performed with living and dead cells under aerobic or anaerobic conditions. Mercury content in the system algae/nutrient medium decreased from 0.35 ug Hg to 0.15 ug in 12 hrs in the living cell suspension under aerobic and anaerobic conditions, and remained at that level for 48 hrs. Mercury in the cell-free nutrient medium decreased slightly to 30 ug Hg and in controls (newly prepared nutrient medium) showed no decline over the test period. The decrease in mercury concentration was due to a reduction of Hg^{2+} to Hg^0, probably caused by extracellular enzymes. Monomethyl or dimethyl mercury could not be detected as intermediate compounds.

3049. Manson, J.M. and E.J. O'Flaherty. 1978. Effects of cadmium on salamander survival and limb regeneration. Environmental Research 16:62-69.

Salamanders, *Notophthalmus viridescens*, with amputated forelimbs, were held in water with 0.0, 2.25, 4.50, or 6.75 mg Cd/l as cadmium acetate. After 51 days, survival had been linearly reduced by about 35% in salamanders in 2.25 mg Cd/l, 45% in 4.50 mg/l, and 80% in 6.75 mg/l. Limb regeneration was begun in 40% of controls by day 22, but in <5% of any surviving Cd-exposed animals. Regeneration had started in all groups except 6.75 mg Cd/l by day 36, and some regeneration was observed in 70 to 100% of all Cd-exposed salamanders and controls on day 51. Amount of regeneration of each limb decreased with increasing Cd concentration. Effects of cadmium on formation of abnormal limb skeletal structures was also noted.

3050. Martin, P.H. 1978. On the radioactivity in the marine environment of the Straits of Malacca. Health Physics 35:574-575.

Average concentrations of uranium-238 and thorium-232 (mg/kg dry wt), and cesium-137 (pCi/kg dry wt) in the Straits of Malacca off Malaysia were: near-shore topsoils, 5.1, 10.6, and 41.0, respectively; marine sediments, 0.5, 2.6, and below quantitative determination; and prawns, Penaeus sp., detectable but below quantitative levels for all three elements.

3051. Miramand, P. and M. Unsal. 1978. Acute toxicity of vanadium to some marine benthic and phytoplanktonic species. Chemosphere 10:827-832. (In French, English abstract).

Acute toxicity of vanadium, as sodium metavanadate, to three benthic species (crabs Carcinus maenas, mussels Mytilus galloprovincialis, and annelids Nereis diversicolor) and three phytoplanktonic species (Dunaliella marina, Prorocentrum micans, and Asterionella japonica) were studied. In general, phytoplankton were more sensitive than benthic organisms. From LC-50 (9 day) values, the species studied can be classified in the following decreasing order of sensitivity: D. marina (0.5 mg V/1), A. japonica (2.0), P. micans (3.0), N. diversicolor (10.0), C. maenas (35.0), M. galloprovincialis (65.0).

3052. Moss, J.L. 1978. Toxicity of selected chemicals to the fairy shrimp, Streptocephalus seali, under laboratory and field conditions. Prog. Fish-Cult. 40:158-160.

Laboratory toxicity tests were conducted with six chemicals, including potassium permanganate, to determine effect on survival of fairy shrimp. Potassium permanganate (0.5 to 4.0 mg/l) produced 100% mortality in less than 24 hrs. Pond treatments with potassium permanganate (1.0 and 2.0 mg/l) produced more rapid mortality than Dylox (0.25 mg/l). Neither chemical completely eliminated all fairy shrimp from ponds, except in isolated cases.

3053. Mudroch, A. and J. Capobianco. 1978. Study of selected metals in marshes on Lake St. Clair, Ontario. Arch. Hydrobiol. 84:87-108.

Relationship between concentration of Cd, Co, Cr, Cu, Ni, Pb, and Zn in sediments and marshwater, and uptake by plants (*Typha latifolia*, *Carex laucustris*, *Pontederia cordata*, *Lythrum salicaria*, *Nymphaea odorata*, and *Myriophyllum heterophyllum*) and algae (*Chara* sp.) from the east shore of Lake St. Clair, Ontario, was investigated over the 1976 growing season. Accumulation of metals varied between plant species and was affected by metal concentrations in sediments and water in a complex way. Variations occurred in metal uptake by the same species growing in different plant communities. Average concentrations in plants, in mg/kg dry wt, ranged from <1.0 to 3.2 for Cd, 1.1 to 12.8 for Co, 1.3 to 6.0 for Cr, 1.9 to 5.3 for Cu, 1.2 to 10.9 for Ni, 3.6 to 35.1 for Pb, and 11.5 to 25.5 for Zn. *Carex* accumulated the largest amount of zinc, while *Myriophyllum* and *Chara* contained maximum concentrations of the other metals. Metal content of roots of *Typha*, *Lythrum*, and *Pontederia* were higher than above ground biomass. Metal levels in the top 20 cm of sediment, in mg/kg dry wt, were 1.0 to 1.3 for Cd, 5.6 to 9.6 Co, 5.0 to 24.9 Cr, 7.0 to 43.7 Cu, 9.2 to 24.1 Ni, 18.2 to 63.7 Pb, and 29.0 to 123.4 Zn. Maximum marshwater concentrations, in mg/l, were 1.0 Cd, 0.001 Co, 1.0 Cr, 9.0 Cu, 0.001 Ni, 50 Pb, and 54 Zn.

3054. Newkirk, G. 1978. Interaction of genotype and salinity in larvae of the oyster *Crassostrea virginica*. Marine Biology 48:227-234.

Adult oysters were obtained from 4 populations and spawned in the laboratory. Larvae from within-population crosses and hybrid crosses raised at 4 salinities between 12 and 30 o/oo showed no significant differences in survival. However, one set of hybrids did show dominance in survival. There were significant genotype-environment interaction differences between populations in growth rate, which depended upon salinity. Non-additive genetic effects in the hybrid crosses were observed, but direction and magnitude was dependent upon salinity. There was as much difference between populations from the same estuary as between populations from geographically isolated populations.

3055. Nielsen, S.A. 1974. Vertical concentration gradients of heavy metals in cultured mussels. New Zealand Jour. Marine Freshwater Res. 8:631-636.

Cultured mussels, *Perna canaliculus*, from two widely separated locations in N.Z. were analysed for variations in content of selected metals with water depth. *Perna*, which are grown on vertically suspended ropes to a depth of 9 m, were analysed for Cd, Pb, Fe and Zn at 1 m intervals. At one location (Kenepuru Sound), Cd, Pb, and Fe increased with depth, Zn decreased. At the second location (Waiheke I.), concentrations of all 4 metals remained essentially constant with depth. Author attributes differences in vertical concentration gradients to differences in mixing of the water column at the two locations. This may also cause variations in the type of food organisms with depth, or in variations in the ratio of particulate:dissolved metal levels with depth. Either or both of these conditions could result in differences in the bioavailability of metals with depth.

3056. Nielsen, S.A. and A. Nathan. 1975. Heavy metal levels in New Zealand molluscs. New Zealand Jour. Marine Freshwater Res. 9:467-481.

Cadmium, lead, copper, mercury, zinc, and iron concentrations were determined in 13 species of edible molluscs, including all species normally found in N.Z., from 199 sites. Average concentrations, in mg/kg wet wt soft parts, were:

	Cd	Pb	Zn	Cu
Crassostrea glomerata	1.3	0.9	337	40
Ostrea lutaria	3.9	0.7	66	11
Perna canaliculus	0.3	1.8	21	2
Mytilus edulis	0.6	0.7	14	8
Pecten novaezelandiae	0.2	1.1	21	1
stomach	137	1.2	24	10
gonad	1.5	0.3	27	2
adductor muscle	0.5	0.5	16	7
Haliotis iris	0.2	0.5	13	-
Paphies ventricosa	0.1	0.8	10	2
Paphies australis	0.1	0.4	13	1
Paphies subtriangulata	0.3	0.7	7	5
Aulacomya maoriana	0.9	0.5	8	9
Anomia walteri	2.0	0.4	19	14
Chione stutchburyi	0.2	1.8	10	-
Modiolus neozelanicus	0.04	-	-	-

Iron was relatively high in most species; values up to 280 mg/kg wet wt soft parts were found in *Perna canaliculus*. For all metals, wide variations occurred between locations; explanations for some of these variations are presented.

3057. Ogino, C. and H. Takeda. 1978. Requirements of rainbow trout for dietary calcium and phosphorus. Bull. Japan. Soc. Sci. Fish. 44:1019-1022. (In Japanese, English abstract).

Trout were fed purified diets for 6 weeks containing from 300 to 3400 mg Ca/kg and from 650 to 10,900 mg P/kg. The rearing water contained 20 to 23 mg Ca/l and 0.002 mg P/l. Dietary P levels greatly affected growth, body composition, and mineral composition (Ca, P, and Mg) of the body and vertebrae. Dietary calcium levels did not influence growth or body composition. The available phosphorus level required to maintain a normal growth of experimental fish was estimated to be 0.7 to 0.8% of their diet.

3058. Ogino, C. and G.-Y. Yang. 1978. Requirement of rainbow trout for dietary zinc. Bull. Japan. Soc. Sci. Fish. 44:1015-1018.

Trout were fed diets containing from 1.0 to 30.0 mg/kg of zinc. Zinc was an essential trace element in the diet of trout though rearing water contained a low concentration (11 ug/l) of this element. Fish fed a diet low in zinc content (1.0 mg/kg) showed an extremely low growth rate, high mortality, and suffered from cataracts in the eyes and erosion of fins and skin. Dietary zinc levels also influenced digestibility of protein and, to a lesser degree, carbohydrates. Proximate body composition and contents of Cu, Fe, and Zn in different organs varied according to dietary zinc. Judging from the growth rate, an adequate zinc content in the diet of rainbow trout was estimated to be 15 to 30 mg/kg.

3059. Payton, P.H., S.B. Hild, C.U. Oertti, and A.D. Suttle, Jr. 1977. Strontium-90 in the western Gulf of Mexico. Health Physics 33:143-145.

Strontium-90 concentrations, normalized to calcium content, in marine invertebrates collected in 1972 from the western Gulf of Mexico were: 4.22 nCi Sr-90/kg Ca in coral Montastrea cavernosa, 0.68 in hermit crab Clibanarius vittatus, 0.06 in two bivalve molluscs Amusium papyraceum and Laevicardium laevigatum, and ranged from 0.02 to 0.57 in 9 species of gastropod molluscs. The freshwater clam, Cyrtonaias tampicoensis, contained 0.04 nCi Sr-90/kg Ca. Gulf seawater contained 0.0001 nCi/l, or 1.37 nCi Sr-90/kg Ca.

3060. Pentreath, R.J. 1978. ^{237}Pu experiments with the plaice Pleuronectes platessa. Marine Biology 48:327-335.

Metabolism of Pu-237 (a high specific activity, gamma-emitting isotope of plutonium) by plaice, P. platessa, was studied. Very little of the isotope was incorporated into fish after 2 months exposure to labelled water or sediment. Oral retention from labelled foods, annelids Nereis diversicolor, or hepatopancreas of crabs Carcinus maenas, was also poor. Apart from the gut itself, no incorporation of Pu-237 could be demonstrated. Injected Pu-237 was eliminated very slowly; rate of Pu-237 loss was inversely related to growth rate of fish. Growing fish incorporated a relatively larger fraction of Pu-237 body burden into skeletal material at the expense of the isotopic content of liver. Very little Pu-237 was incorporated into muscle.

3061. Pentreath, R.J. 1978. ^{237}Pu experiments with the thornback ray Raja clavata. Marine Biology 48:337-342.

Metabolism of Pu-237 (a high specific activity, gamma-emitting isotope of plutonium) by R. clavata was studied. Unlike plaice, Pleuronectes platessa, thornback rays absorbed plutonium across the gut wall. Liver accumulated up to 0.2% of Pu-237 given in a single labelled meal of annelid, Nereis diversicolor, or hepatopancreas of crab, Carcinus maenas, after 12 days. Direct injection of the isotope into muscle resulted in extremely slow rates of elimination from rays. Highest internal concentrations were: spleen, to 935 cpm/g wet wt; liver, to 446; and gill, to 278. The largest fractions of Pu-237 whole-body burden, however, were in liver, 12-27%, and skeleton, 10-26%.

3062. Phillips, G.R. and D.R. Buhler. 1978. The relative contributions of methylmercury from food or water to rainbow trout (Salmo gairdneri) in a controlled laboratory environment. Trans. Amer. Fish. Soc. 107:853-861.

Trout accumulated methylmercury linearly during 24 days when continually exposed to methylmercury. Exposure was by means of water solutions (0.07-1.33 ug Hg/l), food consumption (8.0-380.5 ug Hg/kg fish/day) or both. Methylmercury accumulated from one source had no influence on rate of uptake from the second source. Accumulation from both sources was quantitatively additive, which validates a frequently used assumption. Trout exposed to 1.33 ug Hg/l and fed 3080 ug Hg/kg had methylmercury accumulation rate of 4120 ug Hg/kg wet wt/day and consumption rate of 379 ug Hg/kg/day. Maximum body burdens reached 8630 ug Hg/kg wet wt under these conditions. Food consumption rate and therefore growth rate had no influence on rate of mercury accumulation from water. Nearly 70% of methylmercury ingested and 10% of methylmercury passed over gills was assimilated.

3063. Roberts, E., R. Spewak, S. Stryker, and S. Tracey. 1975. Compilation of state data for eight selected toxic substances, vols. 1-5. U.S. Environ. Protect. Agency Repts. EPA 560/7-75-001-1 through EPA 560/7-75-001-5. Avail. as PB-248-660 through PB-248-664 from Nat. Tech. Inform. Serv., U.S. Dept. of Comm., Springfield, VA 22151.

Compilation of monitoring data from agencies in 20 states on biological effects of arsenic, beryllium, cadmium, chromium, lead, mercury, and other compounds was completed. Emphasis was on residue concentrations in plants, fish, shellfish, ducks, terrestrial wildlife, humans, water, and sediment. Summaries of state agency data and monitoring capabilities, are discussed. Volumes also include a directory on each monitoring agency and a bibliography of 129 citations.

3064. Sidwell, V.D., A.L. Loomis, K.J. Loomis, P.R. Foncannon, and D.H. Buzzell. 1978. Composition of the edible portion of raw (fresh or frozen) crustaceans, finfish, and mollusks. III. microelements. Marine Fish. Rev. 40(9):1-20.

This report summarizes data from 224 publications on trace metal contents in flesh of commonly eaten species of marine and freshwater crustaceans, elasmobranchs, finfishes, molluscs, echinoderms, mammals, and waterfowl. Data are presented on the following elements: copper, iron, zinc, manganese, mercury, organic mercury, lead, arsenic, silver, cadmium, cobalt, selenium, chromium, vanadium, tin, aluminum, nickel, barium, and molybdenum.

3065. Sikes, C.S. 1977. Calcium and cation sorption by Cladophora from the Great Lakes. Jour. Great Lakes Res., Internat. Assn. Great Lakes Res. 3:100-105.

Sorption of calcium and strontium was studied in the alga Cladophora glomerata. Total calcium uptake was directly proportional to concentration in the medium at low levels (2-20 mg Ca/l). However, algae became saturated at high Ca levels after 4 weeks (13,000 mg Ca/kg at 20-100 mg Ca/l). Uptake was largely an ion-exchange reaction favoring polyvalent cations of small hydrated radius. Strontium uptake mimicked that of calcium, but the alga preferentially adsorbed Sr over Ca by 1.25X. Maximum concentration factors were 775 for Ca and 1070 for Sr. Calcium and Sr sorption by Cladophora from each of the Great Lakes had the same cationic sorptive capacity. Results of experiments with a Lake Michigan isolate should, therefore, be applicable to natural populations of the alga. Turbulence and pH contributed to the variability of calcium sorption by Cladophora by affecting diffusion gradients and solubility of calcium, respectively.

3066. Singh, H. and J.S. Marshall. 1977. A preliminary assessment of ^{239,240}Pu concentrations in a stream near Argonne National Laboratory. Health Physics 32:195-198.

Low level radioactive wastes empty into Sawmill Creek, Illinois, from Argonne's nuclear facilities following clean-up and dilution in the Argonne National Laboratory sewage plant. Plutonium-239 concentrations detected in the creek were: unfiltered water, upstream 0.41 fCi/l and at discharge 102; sediment, upstream 1490 fCi/kg wet wt and downstream 8900; algae Cladophora sp., upstream 314 fCi/kg wet wt and downstream 5160; isopods, upstream 2880 fCi/kg wet wt and downstream 3920; sunfishes (Centrarchidae), downstream 142 fCi/kg wet wt in gill and 1040 in gastrointestinal tract. Pu-239 ratios of downstream concentration to upstream were 16 in Cladophora, 1.4 in isopods, 6.3 in fish gills, 46 in fish G.I. tract, 246 in unfiltered water, and 6.0 in sediments.

3067. Smart, R.M. and J.W. Barko. 1978. Influence of sediment salinity and nutrients on the physiological ecology of selected salt marsh plants. Estuarine Coastal Marine Science 7:487-495.

Influence of salinity and nutrients on Spartina alterniflora, S. foliosa, S. patens, and Distichlis spicata was studied under simulated tidal inundation. Growth differences were attributed to differences in sediment salinity and nutrients. Relative salinity tolerances of the four species were comparable to field results reported in literature. Salinity tolerance, in decreasing order, was: D. spicata, S. alterniflora, S. foliosa, and S. patens. The species studied are known to be salt secreting, and were shown to be capable of ion exclusion which, in some cases, resulted in increased sediment salinity. Selective uptake of potassium was demonstrated; tissue potassium was linearly related to sediment salinity. Importance of salinity on plant growth in natural marshes is discussed in relation to other environmental factors.

3068. Sosnowski, S.L. and J.H. Gentile. 1978. Toxicological comparison of natural and cultured populations of Acartia tonsa to cadmium, copper, and mercury. Jour. Fish. Res. Bd. Canada 35:1366-1369.

Cultured copepods, A. tonsa, manifested a reproducible toxicological response through six generations, with no significant differences in responses of F_1 and F_6 generations to salts of cadmium, copper, and mercury. Cultured and field populations (parental) exposed to cadmium showed similar toxicological effects. The response variability of cultured populations was less than in field populations. LC-50 (96 hr) concentrations for cultured (F_1) populations were 90 ug Cd/l, 31 ug Cu/l, and 10 ug Hg/l. Presence and abundance of ova, and unicellular glands in the circumesophogeal region were useful as criteria for evaluating the nutritional condition of test populations.

3069. Tamura, Y., T. Maki, H. Yamada, Y. Shimamura, S. Ochiai, S. Nishigaki, and Y. Kimura. 1975. Studies on the behavior of accumulation of trace elements in fishes. III. accumulation of selenium and mercury in various tissues of tuna. Tokyo Toritsu Eisei Kenkyusho Nenpo 26(1):200-204. (Translated by Translation Bur., Multilingual Serv. Div., Dept. Secr. State Canada, Fish. Mar. Serv. No. 3994, 1977:11 pp).

Bluefin tuna, albacore, bigeye tuna, yellowfin tuna, and bonito from a Tokyo market were analyzed for selenium, total mercury and methylmercury. Maximum tissue levels of Se were between 10 and 15 mg/kg wet wt in liver, spleen, and kidney and ranged from 0.5 to 1.3 mg/kg in white muscle. Maximum concentrations of total Hg ranged from 0.1 to 0.7 mg/kg wet wt in spleen, liver, and muscle, and were 0.3 mg/l in blood. Percentage of methyl-Hg of total Hg averaged 93% in white muscle of tuna, but was lower, about 55%, in red muscle and liver. Levels of Se exceeded Hg in all tissues; the least molar ratio was 5.8:1 in muscle and >100:1 in other organs. No correlation between Se and total Hg accumulation was observed. Higher levels of Se in muscle tissues were found on the side of the abdomen, while total Hg tended to be located higher in back muscle. Accumulation of Se in red muscle was 7X higher than in white muscle.

3070. Townes, M.M. 1978. The participation of ionic strength and pH in the contraction induced in Vorticella by calcium and magnesium. Comp. Biochem. Physiol. 61A:555-558.

Glycerinated stalks of the protozoan, Vorticella convallaria, can be induced to contract by application of either Ca^{2+} or Mg^{2+}. Contractions varied as a function of pH and ionic strength (NaCl) of bathing fluids. Coiling in the presence of Mg^{2+} is atypical while Ca^{2+}-contractions are typical of living vorticellid coiling. Increasing ionic strength prevented Mg^{2+} coiling. Ca^{2+} coiling at pH 6.8 and 7.0 was inhibited by low ionic strength and enhanced by high ionic strength. High concentrations of Ca^{2+} prevented the ionic strength repression of contractions.

3071. Umehara, S. and M. Oguri. 1978. Effects of environmental calcium content on plasma calcium levels in goldfish. Bull. Japan. Soc. Sci. Fish. 44:827-833.

Plasma Ca^{2+} level increased markedly, up to about 5.0 meq/l, in goldfish, Carassius auratus, within 7 days of transfer to 1/3 strength seawater, and remained high for 21 days. Plasma K^+ and Na^+ also increased to about 5.0 and 180 meq/l, respectively, in 1/3 seawater. Cation levels did not change in goldfish transferred to Ca^{2+}-rich freshwater. In goldfish in 1/3 seawater, histological changes in the corpuscle of Stannius occurred, water movement rate in intestine increased, and Ca^{2+}-activated ATPase activity in gill increased. These changes were not observed in goldfish held in Ca^{2+}-rich freshwater.

3072. Weis, J.S. 1978. Interactions of methylmercury, cadmium, and salinity on regeneration in the fiddler crabs Uca pugilator, U. pugnax and U. minax. Marine Biology 49:119-124.

After multiple autotomy in 3 species of fiddler crabs, methylmercury at 0.5 mg/l, or cadmium at 2.0 mg/l, retarded limb regeneration and ecdysis. When crabs in seawater were exposed to a mixture of both metals, the retardation effect was increased, indicating additive interaction. In 50% seawater (15 o/oo S), effects of cadmium were greatly intensified so that growth of limb buds was extremely slow, or nil. When methylmercury was present at the same time, severe effects of Cd were somewhat lessened, indicating an antagonistic interaction. Adding additional calcium to 50% seawater also decreased severity of cadmium effect, thus supporting the idea of a calcium-cadmium competition.

3073. Westerman, A.G. and W.J. Birge. 1978. Accelerated rate of albinism in channel catfish exposed to metals. Progr. Fish-Culturist 40:143-146.

Salts of As, Cd, Cu, Hg, Se, and Zn were shown to increase the incidence of albinism during 5 years of experiments with channel catfish, Ictalurus punctatus. Metal-induced albinism resulted from exposure of both adult fish and eggs. In egg bioassays, exposed populations consistently exhibited higher percentages, up to 6.3%, of albinos in fry than controls; however frequencies did not vary significantly among the six metals or among exposure concentrations which ranged from 0.5 to 250 ug/l. Metal contamination in a hatchery water supply yielded frequencies of albinos corresponding directly with those observed for metal-exposed laboratory populations. Since albinism is deleterious to fish survival and production, caution is recommended when using metallic compounds in hatcheries. Tests for albinism may prove useful in screening aquatic contaminants for mutagenic potential.

3074. Willis, J.N. and N.Y. Jones. 1977. The use of uniform labeling with zinc-65 to measure stable zinc turnover in the mosquito fish, Gambusia affinis - I. retention. Health Physics 32:381-387.

Juveniles of G. affinis, were reared for about 100 days in water uniformly labelled with 1.0 mCi Zn-65 Cl_2 plus $ZnSO_4$ (for a total concentration of 200 ug Zn/l), until they attained the specific activity of the environment. Specific activities of zinc, in nCi Zn-65/ug Zn, after 100 days were 1.7 in filtered water, 1.1 in particulate water, 1.3 in algae, and 1.2 in mosquitofish. Retention of Zn-65 in these fish was monitored over 120 days in a non-labeled zinc environment. Analysis of the retention curve yielded three mathematical reservoirs of stable Zn each containing 8.7, 4.3 and 91.1% of the element with measured rate constants of 0.280, 0.051 and 0.003/day, respectively.

3075. Wrench, J.J. 1978. Selenium metabolism in the marine phytoplankters Tetraselmis tetrathele and Dunaliella minuta. Marine Biology 49:231-236.

Radioactive selenite-75 was used to investigate metabolic transformation of inorganic selenium by 2 species of marine algae. The majority of radioselenium taken up from culture media during growth became associated with cellular protein. A small quantity of this protein-bound Se could be volatilized by treatment with strong acid, suggesting the presence of hydrogen selenide. However, the principal fraction of selenium was integrated into the primary protein structure, as revealed by the presence of seleno-analogues of the sulphur amino acids. Selenium amino acids were also detected in non-protein extracts.

3076. Yannai, S. and K. Sachs. 1978. Mercury compounds in some eastern Mediterranean fishes, invertebrates, and their habitats. Environmental Research 16:408-418.

Total mercury content of the common edible species of fishes and invertebrates taken along the Mediterranean coast of Israel was determined. Size (reflecting age) and position in the food chain were the factors which most affected concentration of total mercury in fish. In most cases, carnivorous fish had higher mercury levels than herbivorous and omnivorous species. Among the fishes with highest mercury content in edible tissues (i.e., Upeneus moluccensis with 0.44 to 0.56 mg Hg/kg wet wt, Merluccius merluccius with 0.88, Saurida undosquamis with 0.51, and Sphyraena sphyraena with 0.62 mg/kg), methylmercury concentrations accounted for 77 to 100% of total mercury. Barnacles Balanus eburnus and B. amphitrite, tunicate Ciona intentinalus, plus serpulid worms, other tunicates, crustaceans, molluscs, and bryozoan species collected along the northern Mediterranean coast of Israel contained total mercury concentrations of 0.02 to 0.38 mg/kg wet wt. These benthic invertebrates reflected concentrations in their habitat, being with tissue concentrations higher in animals from the more heavily polluted Haifa Bay and environs. Sediment mercury concentrations were 0.04 to 0.05 mg/kg dry wt in sites with no pollution and 0.01 to 0.70 mg/kg in sites with industrial or domestic pollution or both. Water concentrations ranged from 0.01 to 0.07 ug Hg/l in unpolluted and 0.02 to 1.90 ug/l in polluted environments. Only in the immediate vicinity of a chemical plant outfall were concentrations of mercury in water and sediment significantly greater than in other sampling stations along the northern coast.

3077. Akesson, B. and J.D. Costlow. 1978. Effects of temperature and salinity on the life cycle of *Ophryotrocha diadema* (Polychaeta, Dorvilleidae). *Ophelia* 17:215-229.

Mortality, maturation, and reproductive success of various life stages of a stenohaline polychaete worm was observed in salinities from 15 to 45 o/oo at temperatures of 15 to 25 C. At 15 and 20 o/oo S, all larvae and adults died within 2 days. Optimum conditions for survival were obtained at 35 o/oo S and 18 C. Optimum egg production was at 35 o/oo S and 25 C. Maximum growth rate and shortest development time to sexual maturity were at 30 and 35 o/oo S and 25 C. The number of eggs per egg mass was salinity dependent, with a maximum at 35 o/oo. At low temperatures of 15 and 18 C, survival was better at 40 than at 25 o/oo S; at 21 and 25 C, that pattern was reversed. Growth rate indicated a similar change, which occurred between 15 and 18 C. At 15 C, larvae maintained at 40 o/oo S exhibit superior survival, but at higher temperatures, greater survival was observed among larvae reared at 25 o/oo.

3078. Anon. 1975. Preliminary investigation of effects on the environment of boron, indium, nickel, selenium, tin, vanadium and their compounds. volume I. boron. U.S. Environ. Protect. Agen. Rept. EPA-560/2-75-005a. Avail. as PB-245 984 from Nat. Tech. Inform. Serv., U.S. Dept. Commerce, Springfield, VA 22151:111 pp.

A comprehensive review of 225 articles was conducted on the physical and chemical properties of boron, environmental exposure factors related to its consumption and use, health and environmental effects resulting from B exposure, and applicable regulations and standards governing its use. Boron is found at concentrations of 10 to 30 mg/kg in soils, about 0.1 mg/l in surface waters, and 4.5 mg/l in seawater. It enters the environment at a rate of approximately 32,000 metric tons B/year for the United States; most ends up in the waters. About one-half enters water directly from laundry products and sewage. Effects of B have been studied with bacteria, protozoans, insects, fish, birds, and mammals. Boron compounds are absorbed by intestine, mucous membranes, and skin. Excretion is mainly via urine, but complete excretion is slow and boron may accumulate. Inorganic borates are toxic, apparently complexing hydroxy compounds and interfering with protein synthesis. Organoborate compounds exert physiological effects on the peripheral and central nervous system, acting as spasmolytics, sedatives and convulsants, depending upon the structure. Boranes produce toxic effects by creating embolisms of hydrogen gas as they react with tissue. No boron carcinogenicity has been reported. Erythema and swelling may develop in individuals sensitive to boron. Boric acid is a potent teratogen when applied directly to frog or chick embryo. Its compounds are selectively accumulated by some types of tumors. Boron is a growth requirement for plants and not animals, but excess amounts are phytotoxic. Plant species vary greatly in sensitivity to B toxicity. Long-range effects of boron compounds on birds, fish, and other aquatic organisms have not been investigated. Medical and household use of boric acid solutions as antiseptics has led to numerous accidental poisonings through ingestion or absorption through skin, particularly in infants. Contamination of air with boron compounds does not appear to pose an environmental problem. Future build-up of boron in ground waters could cause detrimental effects to aquatic and other species of plants and animals. Plant toxicity effects could become generalized if boron-containing cleansing agents become more widely used. Acute toxicity of humans to boric acid has led to poisonings which could probably have been prevented by minimal use of warning labels or substitution.

3079. Anon. 1975. Preliminary investigation of effects on the environment of boron, indium, nickel, selenium, tin, vanadium and their compounds. volume III. nickel. U.S. Environ. Protect. Agen. Rept. EPA-560/2-75-005c. Avail. as PB-245 986 through Nat. Tech. Inform. Serv., U.S Dept. Commerce, Springfield, VA 22151:89 pp.

A comprehensive review of 244 articles was conducted on the physical and chemical properties of nickel, environmental exposure factors related to its consumption and use, health and environmental effects resulting from Ni exposure, and regulations and standards governing its use. Of the estimated 4895 metric tons/year of nickel entering the environment for the United States, over 90% arises from combustion of fuel oil and enters the atmosphere as oxides. A significant amount of nickel waste (15,000 kg Ni/year) arises from the electroplating industry. Waste effluents from nickel sulfate production are insignificant in comparison to other sources. Toxic concentrations of nickel in soil and waters occur both naturally and as a result of man's activities in foreign countries (including Canada), but have not been reported in the United States except as local effects of plating bath and similar effluents. Many persons exhibit allergic reactions to nickel and nickel compounds. The concentration at or below which no contact allergic reaction occurs in nickel-sensitive persons is 1.0 umole Ni/l (about 59 ug/l). Sensitivity to nickel often occurs concurrently with sensitivity to cobalt and chromium. Various nickel compounds, particularly sulfide and carbonyl, are known carcinogens, and various environmental exposures to nickel in other countries seem to correlate with increased incidence of tumors in man. Effects of Ni have been observed with bacteria and yeasts, algae and higher plants, fungi, protozoans, annelids, crustaceans, echinoderms, molluscs, insects, fish, amphibians, birds, and mammals. Nickel is absorbed through intestines, lungs, and abraded skin; urinary excretion is the principal mode of elimination. Nickel is present in both an ultrafiltrable and a protein-bound form in blood. A dietary requirement for Ni has not been established. Nickel ions can replace calcium ions in the generation of action potentials in muscle, but duration of the potential is increased. Nickel is absorbed by plants through roots, and phytotoxicity occurs with excessive nickel levels. Nickel ions inhibit growth of various microorganisms and produce a progressive narcosis in Paramecium. Although Ni-containing industrial wastes are probably insignificant except on a very localized basis, nickel content of petroleum has caused a continuing world-wide increase in atmospheric levels of nickel. This source of nickel could pose future health and environmental hazards if the increase continues.

3080. Anon. 1975. Preliminary investigation of effects on the environment of boron, indium, nickel, selenium, tin, vanadium and their compounds. volume IV. selenium. U.S. Environ. Protect. Agen. Rept. EPA-560/2-75-005d. Avail. as PB-245 987 from Nat. Tech. Inform. Serv., U.S. Dept. Commerce, Springfield, VA 22151:92 pp.

A total of 63 articles were reviewed on physical and chemical properties of selenium, environmental exposure factors related to its consumption and use, health and environmental effects resulting from Se exposure, and applicable regulations and standards governing its use. Selenium is beneficial or essential in amounts from trace to mg/kg or mg/l concentrations for humans, animals, and plants, but toxic to animals at concentrations which may exist in the environment. Sensitivity to Se and its compounds is extremely variable in all classes of organisms. Selenium is widely distributed in nature, and is found in greater concentrations associated with sulfide minerals of lead, iron, copper and other metals. The major source of Se is from weathering of natural rock. Selenium entering the environment from activities of man is estimated at 3500 metric tons/year, of which most is attributed to combustion of coal. These contributions are small in comparison to natural sources. Selenium and its compounds are moderately toxic to man; effects disappear when exposure ceases. A number of cases of accidental human poisoning by selenium in well water and by selenium sulfide (dandruff treatment) have been reported. Effects of Se have been observed in algae and higher plants, bacteria and yeasts, crustaceans, molluscs, insects, fish, birds, and mammals. Selenium compounds are absorbed through small intestine and excreted in urine, feces, exhaled air and perspiration. Inorganic selenium salts become tightly bound to protein, binding with free sulfhydryl groups. Organoselenium compounds are metabolized like their sulfur analogs. Selenium is a growth requirement in some animals. Plants are efficient accumulators of selenium, especially organoselenium, but tolerance of plants to selenium varies greatly. Selenium "indicator" plants can accumulate thousands of mg Se/kg without ill effects, and in these plants, Se promotes growth. Concentrations of 25 to 50 mg/kg may produce phytotoxicity in crop plants. Plants and waters high in Se are significant dangers to livestock in seleniferous zones due to the extreme toxicity. Urinary Se levels appear higher in humans ingesting foods raised in seleniferous areas, and chronic and acute cases of poisoning have been reported. Selenium is transmitted from the mother to the fetus. Reduced reproduction rates and weakened offspring occur in selenium-deficient mothers. Excessive selenium may act as teratogens and antitumor agents rather than carcinogens. Selenium compounds inhibit growth in many microorganisms. Animals, plants, and microorganisms reduce selenium, but metabolic oxidation has not been clearly established in any species.

3081. Anon. 1975. Preliminary investigation of effects on the environment of boron, indium, nickel, selenium, tin, vanadium and their compounds. volume V. tin. U.S. Environ. Protect. Agen. Rept. EPA-560/2-75-005e. Avail. as PB-245 988 from Nat. Tech. Inform. Serv., U.S. Dept. Commerce, Springfield, VA 22151:80 pp.

A total of 67 articles were reviewed on the physical and chemical properties of tin, environmental exposure factors related to consumption and use, health and environmental effects resulting from Sn exposure, and on applicable regulations and standards governing use of tin. There is almost no contamination of the environment from processing of tin or its compounds because of recovery and reprocessing of tin wastes. The significant source of environmental contamination is scrap tin cans and tin plate disposal. This tin quickly enters the soil and surface water. One source of contamination of tin is from food stored in tin cans. Although serious health problems from this appear to be unusual, ingestion by humans of tin from cans is continually under surveillance. An unofficial limit in foods of 300 mg Sn/kg has been set. Effects of Sn have been observed in algae and higher plants, fungi, bacteria, protozoans, zooplankton, coelenterates, annelids, echinoderms, molluscs, nematodes, fish, and mammals. Seawater contains about 3.0 ug Sn/l. Tin has been found in algae, but not in most other marine organisms. Inorganic tin compounds are relatively nontoxic. Inorganic tin compounds are poorly absorbed by intestine, and most ingested Sn is excreted in feces. Tin is essential for normal growth in rats. Some Sn may be absorbed through lungs, but inhaled tin oxide particles produce only benign lesions in lung tissue. Tin does not appear to be a carcinogen, teratogen or allergen. Organotin compounds may be absorbed through intestine and skin, and are relatively toxic, depending upon type of organic groups present, and degree of substitution on the Sn. Trialkyltins are the most toxic to mammals, producing cerebral edema and hepatic degeneration. Tetraalkyltins are converted to trialkyltins in liver; thus toxicity symptoms are the same. Dialkytins are excreted in bile, and fatal peritonitis or liver damage may occur. Monoalkyltins produce gastric irritation. Organotins have proven effective as insecticides, molluscides, vermicides, and fungicides. Tin accumulation by plants varies with species. Lichens and mosses contain relatively high levels of Sn. Phytotoxicity can result from excessive applications, but actions of tin on plants are not clearly established.

3082. Anon. 1978. Criteria (dose/effect relationships) for cadmium. Report of a Working Group of Experts prepared for the Commission of the European Communities, Directorate-General for Social Affairs, Health and Safety Directorate. Pergamon Press, N.Y.:202 pp.

Concern for chronic toxicity of cadmium to humans has been raised in part because of the outbreak of Itai-Itai disease in Japan. Cadmium levels in air are very low: 0.0001 to 0.043 ug/m^3 in rural areas and 0.002-0.700 ug/m^3 in cities, reaching 5.0 ug/m^3 near Cd emission sources. Drinking water usually contains <5.0 ug Cd/l. Concentrations of cadmium in most foodstuffs from non-contaminated areas are below 0.1 mg/kg, but liver, kidney, and shellfish can contain much higher levels of cadmium. In general, there is little evidence for Cd concentration in marine food chains; however, oysters, which have a remarkable ability to accumulate cadmium above low levels in seawater, are an exception. For human populations in non-polluted areas, food constitutes the most important source of cadmium (median 43.0 ug/day). Airborn cadmium may be an important source of exposure for human populations close to Cd emission sources or heavy smokers. Total daily absorption of Cd for non-occupationally exposed adults range from 0.36 to 9.80 ug. The main targets of cadmium in humans are the gastrointestinal tract after acute ingestion, and lungs after inhalation during short-term exposure. After long-term exposure, lungs and kidneys are the target organs. The Subcommittee on Toxicity of Metals under the Permanent Commission and International Association of Occupational Health has proposed 200 mg Cd/kg wet wt as the tentative critical concentration in human kidney cortex. The threshold effect level of cadmium by absorption is calculated to be 10-12 ug/day. A list of 560 references is appended.

3083. Augier, H., G. Gilles, and G. Ramonda. 1978. Recherche sur la pollution mercurielle du milieu maritime dans la region de Marseille (Mediterranee, France): partie 1. degre de contamination par le mercure de la phanerogame marine Posidonia oceanica delile a proximite du complexe portuaire et dans la zone de rejet due grand collecteur d'egouts de la ville de Marseille. Environ. Pollution 17:269-285.

Concentrations of mercury were determined in roots, rhizomes and leaves of the marine plant Posidonia oceanica collected from the western Mediterranean Sea in the first half of 1976. Results revealed serious mercury contamination of this plant in the main bay and adjoining small bays of Marseilles, France, with a particularly high level near the outflow of Cortiou sewer, where sediment contained 15.1 mg Hg/kg. Maximum mercury concentrations in Posidonia from 7 sites ranged from 0.14 to 1.07 mg/kg dry wt in roots, 0.12 to 2.50 in rhizomes, and 0.07 to 51.50 in leaves.

3084. Beattie, J.H. and D. Pascoe. 1978. Cadmium uptake by rainbow trout, Salmo gairdneri eggs and alevins. Jour. Fish Biology 13:631-637.

Uptake of cadmium by trout zygotes and alevins from water at concentrations between 0.01 and 50.0 mg Cd/l was investigated. Cadmium content of zygotes and alevins increased with time and exposure concentration. Lower Cd levels were detected in alevins than eggs. Cadmium concentrations, in mg/kg dry wt, after 100 hrs exposure to 10 mg Cd/l, were 570 in zygotes and 8 in alevins. In 50 mg Cd/l, zygotes contained 506 mg Cd/kg dry wt by 10 hrs; all zygotes were dead by 32 hrs. All alevins died within 100 hrs at 50 mg Cd/l. Most cadmium (98%) in zygotes was associated with chorion, which may explain the considerable reduction in cadmium concentration observed in alevins after hatching. Alevins hatching from zygotes exposed to cadmium survived longer in cadmium solutions than alevins with no previous exposure as zygotes. This suggests that pretreatment of zygotes with Cd serves some protective function. Behavioral and pathological signs of cadmium poisoning such as erratic swimming and blood clotting in alevins were observed.

3085. Benoit, D.A. and G.W. Holcombe. 1978. Toxic effects of zinc on fathead minnows Pimephales promelas in soft water. Jour. Fish Biology 13:701-708.

A fathead minnow life-cycle exposure to zinc concentrations from 2.0 to 577.0 ug/l was conducted. The most sensitive indicators of zinc toxicity were egg adhesiveness and fragility, which were significantly affected at 145 ug Zn/l and higher, but were not affected at 78 ug Zn/l and lower. These effects occurred shortly after eggs were spawned (during water hardening) and, therefore, were not related to effects on parental fish. Hatchability and survival of larvae were significantly reduced, and deformities at hatching were significantly increased at 295 ug Zn/l and above. Acclimated and unacclimated groups of larvae exposed to identical zinc concentrations for 8 weeks after hatch showed only slight differences in sensitivity.

3086. Bhan, S. and A.P. Mansuri. 1978. Adaptations to osmotic stress in the marine-euryhaline teleost Periophthalmus dipes: tissue water and mineral content. Indian Jour. Marine Sci. 7:134-136.

Water, sodium, potassium, calcium, and phosphorus contents were estimated in white muscle, red muscle, gills, liver, heart, and kidney of P. dipes after adaptation to various concentrations of seawater from full strength to freshwater. Water content did not vary significantly in any tissue after adaptation to various salinities. Sodium, K, Ca, and P levels of different tissues showed a decreasing trend in lowered salinities and absolute freshwater. Authors conclude that this fish has the ability to regulate the mineral status of its tissues according to salinity and becomes acclimatized gradually to different salinities without a significant increase of body water.

3087. Bochenin, V.F., M.Y. Chebotina, and N.V. Kulikov. 1978. Seasonal dynamics in the distribution of ^{90}Sr and Ca between the alga *Chara tomentosa* and the aqueous medium. Soviet Jour. *Ecology* 9(1):39-43.

Between 1974 and 1976, water from Lake B. Miassovo, South Urals, before ice formation contained 4.0 pCi Sr-90/l. Water below ice in winter contained 5.4 to 14.3 pCi/l, and water from melted ice contained 0.2 to 0.7 pCi/l. Concentration of Sr-90, calcium, and total ash in the alga *Chara tomentosa* decreased during winter and increased during spring and summer. Concentrations in alga were 2000 to 7000 pCi Sr-90/kg in winter and 11,000 to 13,000 pCi/kg in summer. Algae contained 30,000 to 80,000 mg Ca/kg winter and 90,000 to 130,000 mg/kg summer. At all times of the year, algae accumulated relatively more Ca than Sr-90.

3088. Carlsson, S. and K. Liden. 1977. Observed concentration factors of ^{137}Cs and potassium in some species of fish and littoral plants from an oligotrophic lake. Soviet Jour. Ecology 8(6):492-495.

Concentration factors of cesium-137 and potassium in some species of fish (*Esox lucius*, *Perca fluviatilis*, *Rutilus rutilus*, *Scardinius erythropthalmus*, *Abramis brama*, and *Tinca tinca*) and aquatic plants (*Carex rostrata*, *Equisetum fluviatile*, and *Nuphar luteum*) from the oligotrophic Lake Ulkesjon, Sweden, were determined during 1961 to 1976. Equilibrium concentration factors of Cs-137 followed a trophic level increase among fish, with 810 for bream (*Abramis*) and 3055 for pike (*Esox*). In plants, concentration factors were high and varied from 255 for *Carex* to 2135 for *Equisetum* growing on soft sediment. Concentration factors of K ranged from 2400 to 2900 in fish and 2800 to 3360 in plants. Time dependence, both between years and between seasons, affected observed concentration factors.

3089. Cember, H., E.H. Curtis, and B.G. Blaylock. 1978. Mercury bioconcentration in fish: temperature and concentration effects. Environ. Pollution 17:311-319.

Mercury bioconcentration factors in bluegill sunfish, *Lepomis macrochirus*, were investigated over 688 hours by exposing fish to CH_3Hg-203 Cl at water temperatures of 9, 21, and 33 C and Hg concentrations of 0.0002, 0.0005, 0.005, and 0.05 mg/l. Bioconcentration factor increased exponentially with water temperature at a rate of 0.066 per degree C. Mercury concentration in water did not influence the bioconcentration factor; but total uptake by fish increased with increasing water Hg levels. At 33 C, bioconcentration was 680 to 1144X over water after 240 hrs, and 2294 to 2454X after 688 hrs exposure to all Hg concentrations. Mercury concentration in whole fish in 0.005 mg Hg/l at 33 C for 688 hrs was about 1.3 mg Hg/kg wet wt. Mortality exceeded 50% under the following conditions during 0.05 mg Hg/l exposure: 360 hrs at 9 C; 240 hrs at 21 C; and 300 hrs at 33 C.

3090. Chang, L.W. 1977. Neurotoxic effects of mercury - a review. Environmental Research 14:329-373.

Neurotoxic effects of mercury, mainly involving mammalian and domesticated aviary systems, are reviewed from approximately 150 references. Pathological findings on Minamata Bay disease are summarized. A working hypothesis on the mechanism of mercury action on nervous system is proposed, based on results of biochemical, physiological, and pathological studies of mercury intoxication.

3091. Chin, B., G.S. Lesowitz, I.A. Bernstein, and B.D. Dinman. 1978. A cellular model for studying accommodation to environmental stressors: a protective response to subtoxic exposure to cadmium. Environmental Research 16:423-431.

Effects of cadmium exposure on the normal cell cycle of slime mold, *Physarum polycephalum*, were tested. Periodic exposure to 56 mg Cd^{2+}/l for 30 min throughout the cell cycle showed two peaks of sensitivity resulting in mitotic delay of almost 200 min, one in early S stage and one in late G_2 stage. Exposure to 11.2 mg Cd^{2+}/l for 30 min in early G_2 (0.45 cycle), which does not delay mitosis, "protected" *Physarum* against a mitotic delay of 105 min from 30 min exposure to 44.8 mg Cd^{2+}/l in late G_2 (0.75 cycle). This protection persisted for at least two cell cycles.

3092. Davies, A.G. 1978. Pollution studies with marine plankton. part II. heavy metals. Adv. Marine Biology 15:381-508.

Effects of heavy metals (including Ag, As, Cd, Co, Cr, Cu, Hg, Mn, Na, Ni, Pb, Po, Se, Si, Sr, Zn, and Zr) and influences of salinity, temperature, and other compounds on marine phytoplankton and zooplankton are reviewed. Natural metal concentrations in water and organisms, sublethal and lethal toxicity, and metal turnover in laboratory and natural populations are discussed. Author concludes that if toxicity is determined by levels of uptake in organisms rather than ambient water concentrations, differences between laboratory experiments and natural water conditions disappear and experimental results can be used to determine the extent of pollution effects in the natural environment. A list of about 225 references is appended.

3093. El-Hawawi, A.S.N. and P.E. King. 1978. Salinity and temperature tolerance by *Nymphon gracile* (Leach) and *Achelia echinata* (Hodge) (Pycnogonida). Jour. Exp. Marine Biol. Ecol. 33:213-221.

Tolerance of two species of pycnogonids, *Achelia echinata* and *Nymphon gracile*, to a range of salinities (0.0 to 70.0 o/oo), temperatures (15 and 25 C), and relative humidities has been examined. In most instances *N. gracile* was more resistant than *A. echinata*, and is found higher in the littoral zone during warmer summer months and thus likely to be subjected to greater environmental fluctuation. At 15 C, mortality reached 50 percent in less than a day for adults of both species in 3.4 o/oo S, and by 12 days for *A. echinata* and 15 days for *N. gracile* in 17.0 o/oo S. No specimens from either group died over 20 days in 34.0 o/oo S. At higher salinities, mortality reached 50 percent by 13 days for both species in 50 o/oo S, and by 3 and 4 days for *A. echinata* and *N. gracile*, respectively, in 70 o/oo S. Survival was greater for both species in ≤34 o/oo S at 5 C than at 15 C. Adult *N. gracile* were more tolerant to lowered salinity than larvae.

3094. Emery, R.M., D.C. Klopfer and M.C. McShane. 1978. The ecological export of plutonium from a reprocessing waste pond. Health Physics 34:255-269.

A reprocessing waste pond at Hanford near Richland, Washington, has been inventoried to determine quantities of plutonium that have accumulated since its formation in 1944. The ecological behavior of Pu in this pond is similar to that in other contaminated aquatic systems having widely differing limnological characteristics. Since its creation, this pond has received about 1.0 Ci of Pu-239,240 and Pu-238, practically all of which has been retained by sediments. Submerged plants, mainly diatoms and Potamogeton, accumulate >95% of Pu contained in biota. Total plutonium contained in all biota is about 5.0 mCi. Emergent insects are the only direct biological route of export, mobilizing about 5.0 uCi Pu annually, which is the estimated maximum quantity of Pu exported by waterfowl, other birds, and mammals collectively. Pu concentrations were also determined for lower invertebrates, gastropods, and goldfish. There is no apparent significant export by wind, and it is not likely that Pu has migrated to ground water via percolation. Although this pond has a rapid flushing rate, a eutrophic nutrient supply with a diverse biotic profile, and is in contact with an active terrestrial environment, it appears to effectively bind Pu and prevent it from entering pathways to man and other life.

3095. Fendley, T.T., M.N. Manlove, and I.L. Brisbin, Jr. 1977. The accumulation and elimination of radiocesium by naturally contaminated wood ducks. Health Physics 32:415-422.

Accumulation of radiocesium was studied in hand-reared ducks released into a South Carolina swamp habitat which had been contaminated with production reactor effluents. Uptake of radiocesium by the ducks was described as: ln nCi Cs/kg live body wt = 0.36 + 0.18 (days). Sex of bird had no effect on Cs uptake rate. The average estimated time required to attain practical equilibrium was 17.3 days, with a range of 10.2 to 26.8 days. Ducks which were recaptured after attaining equilibrium concentrations in the field, averaging 16.6 nCi Cs/kg live body wt, showed single-component elimination rate curves. Radiocesium elimination under penned conditions was described as: ln % initial body burden = 4.60 - 0.13 (days). Elimination rate and body weight showed a negative linear correlation for penned birds and there was no effect of sex on loss rate. Radiocesium biological half-times averaged 5.6 days with a range of 3.2 to 9.3 days. Calculations based on biological half-times determined from studies with penned birds were successful in accurately predicting both levels and rates of radiocesium accumulation by free-living birds in the field.

3096. Gardner, G.R. 1978. A review of histopathological effects of selected contaminants on some marine organisms. Marine Fisheries Review 40:51-52.

Histological assessment of effects of environmental pollutants, including copper, mercury, silver, and cadmium, to selected marine organisms are briefly reviewed. Vascular and neurosecretory responses are discussed for fish, bivalve molluscs, and crustaceans.

3097. Glickstein, N. 1978. Acute toxicity of mercury and selenium to *Crassostrea gigas* embryos and *Cancer magister* larvae. Marine Biology 49:113-117.

Possible modification of mercury toxicity by selenium in embryos of the Pacific oyster, *C. gigas*, and larvae of the crab, *C. magister*, was investigated. Mercury concentration eliciting abnormal development in 50% of oyster embryos (EC-50) was 5.7 ug/l (48 hr). Mortality in 50% of crab larvae (LC-50) occurred at 6.6 ug/l (96 hr). EC-50 (48 hr) for selenium was >10,000 ug/l for oyster embryos and LC-50 (96 hr) for crab zoeae was 1040 ug Se/l. A high level of selenium (≥5000 ug/l) increased mercury toxicity for both species. Moderate selenium concentrations of 10 to 1000 ug/l decreased mercury toxicity, although no statistical verification could be made. The order of administration of toxicants had no effect on *C. gigas* embryos. Early developmental stages ≤8 hours of oyster embryos were most sensitive to dissolved Hg. Toxicant administration 24 hrs after fertilization resulted in no apparent abnormalities in development.

3098. Hart, B.A. and B.D. Scaife. 1977. Toxicity and bioaccumulation of cadmium in *Chlorella pyrenoidosa*. Environmental Research 14:401-413.

Cultures of green alga, *C. pyrenoidosa*, grown at pH 7 in the presence of 0.0, 0.25, 0.5, and 1.0 mg Cd/l had doubling times of 11, 21, 22, and 35 hours, respectively. Similarly exposed cultures grown at pH 8 had doubling times of 11, 16, 17, and 25 hrs, respectively. *C. pyrenoidosa* concentrated cadmium up to 3600 mg Cd/kg protein over 35 hrs in 0.5 mg Cd/l at pH 7. The amount of Cd accumulated was directly proportional to initial concentration of metal and was dependent upon pH of the medium. No accumulation occurred in the dark, at 4 C, or in dead cells. Cadmium uptake was not affected by calcium, magnesium, molybdenum, copper, zinc, or cobalt in growth medium, but manganese at 0.2

mg/l completely blocked accumulation. Iron may also play a role in regulating Cd accumulation. Cells which had accumulated cadmium fixed atmospheric CO_2 at reduced rates and oxygen evolution was slightly inhibited. The ability of C. pyrenoidosa to accumulate large concentrations of Cd before showing adverse effects may be related to the presence of cadmium-sequestering agent(s) within the cell. Concentration of Cd by this alga could pose a hazard to organisms higher in the freshwater food chain.

3099. Hughes, G.M. and R. Flos. 1978. Zinc content of the gills of rainbow trout (S. gairdneri) after treatment with zinc solutions under normoxic and hypoxic conditions. Jour. Fish Biology 13:717-728.

Forty trout (54-127 g) were divided into 4 groups and treated as follows: normoxic (oxygen level at 150 mm Hg) clean water; hypoxic (oxygen at 60 mm Hg) clean water; normoxic water with 10 mg zinc/l for 10 hrs; or hypoxic water with 10 mg zinc/l for 10 hrs. Zinc content was determined separately for each of the 4 gill arches on each side of the fish. Zinc concentrations were greater following Zn treatments, but no significant difference between hypoxia and normoxia was observed. Gills contained mean levels of 342 mg Zn/kg dry wt with normoxic conditions, 292 mg/kg with hypoxic, 669 mg/kg with normoxic and 10 mg Zn/l, and 528 mg/kg with hypoxic and 10 mg Zn/l. Mean Zn content in individual arches ranged from 597 to 779 mg/kg dry wt with normoxia and 10 mg Zn/l and from 447 to 587 mg/kg with hypoxia and 10 mg Zn/l. Differences in concentrations of zinc were found in different arches whether expressed per gram dry weight or per unit surface area of the secondary lamellae. The first arch had the lowest and the third arch the highest Zn levels under all conditions.

3100. Inman, C.B.E. and A.P.M. Lockwood. 1977. Some effects of methylmercury and lindane on sodium regulation in the amphipod Gammarus duebeni during changes in the salinity of its medium. Comp. Biochem. Physiol. 58C:67-75.

Gammarus exposed to sublethal concentrations of methylmercury (up to 320 ug/l), or lindane in 2% seawater for 1 to 4 days showed reductions in hemolymph sodium concentration from about 250 mM to as low as 210 mM. Lindane-treated animals still had lowered Na concentrations after a subsequent period of 7 days in clean 2% seawater. Prior treatment with sublethal concentrations of methylmercury or lindane resulted in delays of 80 and 120 min, respectively, in the time required for amphipods to increase active Na uptake when transferred from 100 to 2% seawater. Prior treatment also depressed maximal and steady-state sodium transport rates.

3101. Kariya, T., H. Haga, Y. Haga and Y. Kawasaki. 1978. Studies on the post-mortem identification of the pollutant in fish killed by water pollution - XII. cadmium. Bull. Japan. Soc. Sci. Fish. 44:1065-1072.

Toxicity and accumulation of cadmium in goldfish, *Carassius auratus*, were investigated. Cd-plating solution I contained 50,000 mg $Cd(CN)_2$/l and 100,000 mg NaCl/l, solution II 40,000 mg CdO/l and 130,000 mg NaCN/l, and solution III 208,000 mg $CdSO_4 \cdot H_2O$/l. LC-50 (48 hr) values for $CdCl_2$ and solution III were 3.0 to 7.0 mg Cd/l. For Cd-plating solutions I and II it was 0.3 mg Cd/l. The latter solutions had toxicities greater than indicated by CN concentration. Of experimentals held in 0.1 mg Cd/l, higher mortality and higher body cadmium content were observed for non-feeding groups than feeding groups. Almost all non-feeding fish were dead by 70 days, with over 0.2 mg Cd/kg in whole bodies. About half of feeding fish had died by 70 days and contained less than 0.2 mg Cd/kg. After 30 days in 0.1 mg Cd/l, as $CdCl_2$, non-feeding fish contained 0.94 mg Cd/kg in kidney and 0.61 mg/kg in hepatopancreas; feeding fish contained 0.31 mg/kg in kidney and 0.51 in hepatopancreas; and controls had 0.04 and 0.03 mg/kg, respectively. Bone, ovary, and muscle concentrations were lower than other tissues examined for all 3 groups. High cadmium residues were observed in fishes killed with $CdCl_2$, $Cd(CN)_2$, and solution III; in fishes killed with solutions I and II, high cadmium content was observed only in elevated cadmium concentrations. Maximum whole body Cd levels in dead fishes from different solutions were: 4.52 mg Cd/kg in 10 mg Cd/l, as $Cd(CN)_2$, for 6 hrs; 10.7 mg/kg in 684 mg Cd/l, as soln I, for 0.5 hr; 11.4 mg/kg in 700 mg Cd/l, as soln II, for 0.5 hr; and 13.5 mg/kg in 72.4 mg Cd/l, as soln III, for 15 hrs.

3102. Kulikov, N.V., M.Y. Chebotina, and V.F. Bochenin. 1977. Accumulation of ^{90}Sr and ^{137}Cs by components of a charophyte biocenose. Soviet Jour. Ecology 8(1):34-40.

Accumulation of strontium-90 by live charophyte algae (*Chara* spp., *Nitella hialina*, *Nitellopsis obtusa*, *Tolipella prolifera*) was higher than in dead plants or bottom deposits. Coefficients of accumulation (CA) of Sr-90 on a dry wt basis by live algae ranged from 700 to 1700 after 16 days; CA by dead specimens was 200 to 800; and of bottom deposits of algae from 100 to 400. Cesium-137 was accumulated to a greater degree by bottom deposits than by live and dead algae. CA of Cs-137 of both algal groups after 16 days ranged from 100 to 400, and of bottom deposits from 500 to 7000. Coefficients of accumulation of Sr-90 and Cs-137 for all components of charophyte biocenoses were several times higher in natural conditions than in laboratory experiments. For algae and bottom deposits, a positive linear relationship was observed between Sr-90 accumulation and calcium content, and between Cs-137 accumulation and potassium content. Concentrations of Ca in 8 species of algae ranged from 61,000 to 170,000 mg/kg dry wt with a mean of 123,600, and K ranged from 4400 to 24,100 mg/kg dry wt with a range of 9700.

3103. Kulikov, N.V. and V.G. Kulikova. 1977. Accumulation of ^{90}Sr and ^{137}Cs by certain freshwater fish under natural conditions. Soviet Jour. Ecology 8(5):416-420.

Accumulation of Sr-90 and Cs-137 by freshwater fish is influenced by diet and water chemical composition, in particular the content of Ca and K. The direct dependence of Cs-137 accumulation on fish age is demonstrated with pike. No differences in radionuclide accumulation due to sex were found in any species studied. Specimens of *Esox lucius*, *Percus fluviatilis*, *Coregonus lavaretus*, *Rutilus rutilus*, *Leuciscus idus*, *Carassius carassius*, *Tinca tinca*, and *Cyprinus carpio* from two lakes in the South Urals contained Sr-90 concentrations in whole body minus viscera ranging from 340 to 1329 pCi/kg wet wt and Cs-137 from 170 to 2490 pCi/kg. Coefficients of accumulation in fish over water were 155 to 600 for Sr-90 and 100 to 1465 for Cs-137. As age of pike (*Esox*) increased, average Cs-137 level increased from 1111 to 3353 pCi/kg wet wt, while Sr-90, Ca, and K did not change. Accumulation of calcium and potassium in whole pike is related to the chemical composition of water. Ca concentrations in pike ranged from 7200 to 12,300 mg/kg wet wt and for K from 1700 to 2900 mg/kg.

3104. Lavrova, E.A. and Y.V. Natochin. 1978. Sodium and magnesium concentration of environmental water and the water-salt exchange in fish. Soviet Jour. Ecology 9(2):135-140.

A relation between sodium concentrations of environmental water and blood serum from 64 species of fish and elasmobranchs was observed. Sodium concentrations in waters ranged from 0.14 to 465.0 meq/l, and was divided into four groups for this study: I - Na below 0.25 meq/l, II - from 0.48 to 1.1 meq Na/l, III - close to osmotic concentration of blood serum of bony fish, and IV - from 227 to 465 meq Na/l. Lowest blood Na levels were in fish from the least saline waters. Sodium in blood serum of fish collected from group I waters averaged 121 meq/l, and 141 meq/l in blood from group II. Fish from the Baltic, Caspian, Black, White, and Barents Seas contained 159 to 184 meq Na/l. Maximum blood concentrations of 240 meq Na/l were obtained from sharks and rays from the Black Sea. Kidneys are the principal organs which eliminate excess magnesium from blood. After ingestion of magnesium salt, excess Mg was eliminated by a secretory process characteristic of kidneys of fish able to migrate to the sea or marine species. This mechanism was not present in stenohaline freshwater fish. Kidney regulation maintenance of calcium and potassium balance is also discussed.

3105. Lewis, M. 1978. Acute toxicity of copper, zinc and manganese in single and mixed salt solutions to juvenile longfin dace, Agosia chrysogaster. Jour. Fish. Biology 13:695-700.

Acute toxicity of copper, zinc, manganese, and copper-zinc and copper-manganese mixtures were determined for juvenile longfin dace in hard water bioassays (mean = 218 mg $CaCO_3$/l). Copper-zinc was the most lethal toxicant (LC-50 96 hr = 0.21 mg Cu/l and 0.28 mg Zn/l) and exhibited more than additive toxicity, which was in contrast to additive toxicity of copper-manganese mixtures (LC-50 96 hr = 0.45 mg Cu/l and 64.0 mg Mn/l). Toxicity of copper (LC-50 96 hr = 0.86 mg/l) and zinc (0.79 mg/l) to fish was similar. Both were considerably more lethal than manganese (LC-50 96 hr = 130 mg/l).

3106. Li, W.K.W. 1978. Kinetic analysis of interactive effects of cadmium and nitrate on growth of Thalassiosira fluviatilis (Bacillariophyceae). Jour. Phycology 14:454-460.

Effect of cadmium, from 0.0 to 1.0 mg/l, on growth rates of 2 algal species, Thalassiosira fluviatilis and Isochrysis galbana, at non-limiting nutrient concentrations is described. At limiting nitrate concentrations, effect of Cd on growth rate of T. fluviatilis is described by analogy to the general equation of enzyme inhibition in which the reaction involves a single intermediate. When cells are stressed by Cd, not only is maximum growth rate reduced, but half-saturation growth parameter is increased. The value of $\log(k_1/k_2)$ can be used to describe the type and degree of interaction between a nutrient and an inhibitor. k_1 and k_2 are the inhibitor concentrations resulting in 50% growth inhibition as nutrient concentration approaches zero and an infinitely large value, respectively. Results show that for T. fluviatilis, degree of inhibition by Cd is more severe at low than high NO_3^- levels, but difference in severity diminishes as Cd concentration increases.

3107. Marais, J.F.K. 1978. Routine oxygen consumption of Mugil cephalus, Liza dumerili and L. richardsoni at different temperatures and salinities. Marine Biology 50:9-16.

Metabolic rate in fish may be described by the equation $M = aW^b$; where M = metabolic rate, a = intensity of metabolism, W = body weight, and b = the exponent of W. Oxygen consumption studies were undertaken with 3 mullet species to determine the indices b and a. This was done under 5 experimental temperatures (13, 18, 23, 28, 33 C) for M. cephalus and L. dumerili at 1.0 and 35 o/oo S, and for L. richardsoni at 35 o/oo S only. Mean b values were approximately 0.85. The value of a depended on temperature, and increased according to Van't Hoff's Law, except for L. dumerili at 1 o/oo S and L. richardsoni at 35 o/oo S for a temperature increase from 23 to 28 C. Handling of fish influenced metabolic rate and led to increased consumption rates during the first 8 hrs after introduction into respiration chambers. Fasting in L. dumerili resulted in a drop of 27% in oxygen consumption over 6 days, of which 10% occurred over the first 24 hrs. Oxygen consumption of fish displayed diurnal rhythms, with lowest consumption rates at midday and midnight and highest just after sunrise and sunset.

3108. Marchyulenene, E.-D.P. 1978. Exchange of certain radionuclides between the environment and fresh-water algae. Soviet Jour. Ecology 9(2):163-165.

Order of level of accumulation of 4 radionuclides by freshwater algae after 16-day exposure was Ce-144> Ru-106 >Sr-90 >Cs-137. Coefficients of accumulation of Cladophora glomerata, Nitella syncarpa, Nitellopsis obtusa, Chara rudis, and C. vulgaris over water ranged from 900 to 4374 for Ce-144, 110 to 1598 for Ru-106, 16 to 57 for Sr-90, and 4 to 78 for Cs-137. Calcium content in algae ranged from 40,500 to 100,000 mg/kg ash wt, and potassium from 9000 to 47,500 mg/kg ash wt. After 16 days in clean water, *Cladophora* and *Nitella* retained 72 to 83% of accumulated Ce-144, 83% Ru-106, 60 to 70% Sr-90, and 23 to 75% Cs-137. Algal uptake of radionuclides of strontium and cesium depended on season, decreasing 3 to 14X from spring to autumn; cerium and ruthenium uptake did not change during the vegetative season.

3109. Martin, D.F. and M.H. Gonzalez. 1978. Effects of salinity on synthesis of DNA, acidic polysaccharide, and growth in the blue-green alga, *Gomphosphaeria aponina*. Water Research 12:951-955.

Gomphosphaeria was grown in artificial seawater at salinities of 20 to 36 o/oo. Fair to good growth was obtained at all salinities. Highest growth constant was 1.178/day in 30 o/oo S, with an algal doubling time of 0.588 days. Rate of DNA synthesis increased linearly with growth constant above K_e = 0.95/day. Maximum growth rate was 31.88 ug DNA/10^6 cells/day in 30 o/oo S. Linear correlation coefficients were obtained for rate of polysaccharide synthesis and rate of DNA synthesis, as well as for rate of DNA synthesis and synthesis rate of aponin. Aponin is a material isolated from *G. aponina* which has cytolytic activity toward the Florida red tide organism, *Gymnodinium breve*.

3110. Murphy, B.R., G.J. Atchison, and A.W. McIntosh. 1978. Cadmium and zinc in muscle of bluegill (*Lepomis macrochirus*) and largemouth bass (*Micropterus salmoides*) from an industrially contaminated lake. Environ. Pollution 17:253-257.

Cadmium and zinc analyses of 44 largemouth bass and 29 bluegill indicated that fish in an ecosystem heavily contaminated by trace metals accumulate significantly more metal in edible muscle tissue than fish from an uncontaminated ecosystem. Average metal concentrations near an industrial effluent in Palestine Lake, Indiana, were: in water, 17.3 ug Cd/l/ (dissolved) and 30.3 Cd (suspended), and 293 ug Zn/l (dissolved) and 270 Zn (suspended); and in top 5 cm of sediment, 800 mg Cd/kg dry wt and 12,800 mg Zn/kg. Concentrations detected in fish muscle ranged from 0.01 to 1.31 mg Cd/kg dry wt and 18.2 to 158.2 mg Zn/kg dry wt. Bluegill contained significantly greater concentrations of Cd and Zn than bass. Mean levels were 0.431 Cd (bluegill) and 0.075 mg Cd/kg (bass) and 67.8 Zn (bluegill) and 43.3 mg Zn/kg (bass). Small bass contained significantly more Cd than large bass.

Authors concluded that human consumption of these fish is probably not a health hazard unless such fish constitute a major portion of the diet.

3111. Nifontova, M.G. 1977. Effect of isotopic and nonisotopic carriers on the accumulation of ^{90}Sr and ^{137}Cs from aqueous solutions by lichens. Soviet Jour. Ecology 8(6):533-535.

Chlorides of stable strontium and cesium, at 0.1 mM to 0.1 M concentrations, and Sr-90 and Cs-137, at 10 uCi/l and 6 uCi/l, respectively, were added to water to follow accumulation in lichen, Cladonia amaurocraea, over 4 days. Effect of nonisotopic carriers, calcium and potassium, was also determined. Strontium and cesium isotope accumulation by lichen was directly proportional to water concentrations; Ca and K followed a similar pattern. Lichen content of both stable elements rose from 0.001 M to 1.0 M then plateaued as concentrations in solutions increased. Accumulation coefficients (AC) of radionuclides remained almost constant at 1000 as solution concentrations of Sr and Cs increased to 1.0 mM, then AC dropped gradually to about 10-50 with higher concentrations. As Ca and K levels in solution rose above 0.1 mM to highest concentrations used, AC of Sr-90 and Cs-137 decreased linearly to about 10 to 50.

3112. Noel-Lambot, F., C. Gierday, and A. Disteche. 1978. Distribution of Cd, Zn and Cu in liver and gills of the eel Anguilla anguilla with special reference to metallothioneins. Comp. Biochem. Physiol. 61C:177-187.

Distribution of cadmium, zinc, and copper in the soluble fraction of liver and gills of eels adapted to seawater and submitted to chronic or acute Cd exposure was studied. Metal concentrations, in mg/kg wet wt, in whole livers of control eels were 0.9 for Cd, 17.7 for Cu, and 41.3 for Zn. Liver of eels in 200 mg Cd/l for 5 hrs contained 11.7 mg Cd/kg, 13.3 Cu, and 42.7 Zn. Eels in 13 mg Cd/l for 180 days contained 331 Cd, 15 Cu, and 82 Zn in liver. During chronic intoxication, most of the Cd that accumulated in liver and gills is bound to metallothioneins. In the case of acute intoxication, only liver accumulated Cd as Cd-thioneins. Metallothioneins were present in livers of non-Cd-exposed eels, but in lower amounts than in chronically intoxicated specimens. Metallothioneins were principally in the form of Zn and Cu derivatives. In gills, metallothioneins did not exist in detectable amounts. The overall characteristics of metallothioneins isolated from eel liver are very similar to those obtained from mammalian tissues.

3113. Ogino, C., F. Takashima, and J.Y. Chiou. 1978.
Requirement of rainbow trout for dietary magnesium.
Bull. Japan. Soc. Sci. Fish. 44:1105-1108. (In
Japanese, English abstract and tables).

Trout weighing 0.9 g were fed diets containing different amounts of Mg (46 to 779 mg/kg) for 6 weeks. Concentration of Mg in rearing water was 3.1 mg/l. Dietary Mg levels affected appetite, growth, movement of fish, and contents of ash, Mg, and Ca in whole body and vertebrae. Phosphorus levels did not change significantly. With increasing magnesium in diet, whole body Ca decreased from 3.5 to 2.7% of dry wt, Mg increased from 0.08 to 0.15%, and Ca/Mg ratio decreased from 41 to 18. Vertebrae content of Ca decreased from 13.8 to 11.1% of dry wt, Mg increased from 0.10 to 0.27%, and Ca/Mg ratio decreased from 141 to 40, as dietary magnesium increased. Vertebral curvature and histological changes were observed in muscle, pyloric caeca, and gill filaments were observed in Mg-deficient fish. Requirement of trout for dietary Mg was estimated to be 0.06-0.07% of a dry diet or 12-16 mg/kg body wt per day under experimental conditions.

3114. Ostrom, K.M. and T.L. Simpson. 1978. Calcium and the
release from dormancy of freshwater sponge gemmules.
Developmental Biology 64:332-338.

Salts of barium, manganese, strontium, and zinc at 1 mM, and magnesium at 8 mM, inhibit development of dormant gemmules of the freshwater sponge Spongilla lacustris. This inhibition is overcome by 1 mM calcium, so it can be interpreted that Ca divalent ion is essential for germination (cell division). Inhibitory cations have different effective concentrations which indicate differing binding affinities for sites which may normally bind Ca. Ethylene glycol bis (β-aminoethyl ether), N,N-tetraacetic acid does not effect gemmule development at 15 C but stimulates it at 4 C, indicating that a dislocation of endogenous Ca stimulates release from dormancy. Magnesium will only partially substitute for calcium in overcoming inhibition, implying a different specificity for Mg in gemmule development. Calcium is also essential for hatching (cell motility) in this sponge.

3115. Paschoa, A.S. and G.B. Baptista. 1978. Method for calculation of upper limit internal alpha dose rates to aquatic organisms with application to plutonium-239 in plankton. Health Physics 35:404-409.

Estimations were calculated for upper limits of the internal alpha-radiation dose rates received by plankton due to bioaccumulation of plutonium-239. Authors assumed uniform distribution of alpha-emitter throughout the body, constant concentration, and complete absorption of the mean alpha energy. Reported Pu-239 content in marine and freshwater plankton from selected references ranged from 1.9 to 8.4 uCi/kg wet wt in phytoplankton and 1.0 to 9.0 uCi/kg in zooplankton. Upper limit alpha dose rates ranged from 2.1 to 9.1 urad/hr in phytoplankton and 1.1 to 9.8 urad/hr in zooplankton.

3116. Patel, B., S. Patel, M.C. Balani, and S. Pawar. 1978. Flux of certain radionuclides in the blood-clam *Anadara granosa* Linneaus under environmental conditions. Jour. Exp. Marine Biol. Ecol. 35:177-195.

Flux of cesium-137, cerium-144, and ruthenium-106, in the Bombay Harbor, India, ecosystem was measured over six years (1970-1976), during which input of controlled low level radioactive waste was gradually reduced by more than 20X. Of the pelagic and benthic species studied, the arcid clam *Anadara granosa*, showed a specific affinity for all three radionuclides; degree of bioaccumulation was $Ce \geq Ru > Cs$. Concentrations of these nuclides in tissues varied with levels in sediment, which in turn were related to inputs into seawater, maintaining some kind of equilibrium. Highest concentrations in whole bodies of clams were 38 nCi Ru-106/kg dry wt, 36 nCi Ce-144/kg, and 10 nCi Cs-137/kg, at sediment levels of 75, 140, and 260 nCi/kg dry wt, for respective elements. Individual tissue concentrations were also determined. On reaching maximum accumulation, nuclides in the clam population decreased exponentially with time although radioactivity was still available in sediment. Ecological half-times for Ce-144 and Ru-106 were about 3 to 6X longer, and for Ce-137 significantly shorter, than their respective physical half-lives. Ecological half-times were predominantly influenced by environment rather than by biological half-lives, indicating that biological half-lives were much shorter than respective ecological half-lives. Biological half-time of Cs-137 was biphasic; the short-lived component had a half-time of about 3 days and long-lived component about 15 days. Bioaccumulation of cobalt-60 in *A. granosa* increased with time of exposure and reached a level significantly higher than Cs-137, but was independent of ambient concentrations and temperature. Strontium-90 was preferentially deposited in clam shell at higher concentrations (0.10 nCi/kg after 34 days) under higher temperatures of 30-35 C. Generally, clams maintained tissue concentrations of Ce-144, Ru-106, and Cs-137, but not Co-60, through adjusting physiological flux rates, in equilibrium with changing levels in the environment.

3117. Paul, M. and R.N. Johnston. 1978. Absence of a Ca response following ammonia activation of sea urchin eggs. Developmental Biology 67:330-335.

Following insemination of eggs of sea urchins, *Strongylocentrotus purpuratus* and *S. drobachiensis*, rate of Ca uptake and efflux from eggs increase. Both of these components of the egg's Ca response are absent following partial activation with ammonia. This suggests that the "late events" of fertilization, which are activated by ammonia treatment, are not mediated directly by changes in egg Ca. Uptake of calcium from water reached 2.0 nmoles Ca^{2+}/egg sample after 15 minutes following insemination, but was only 0.3 nmoles/egg sample with addition of NH_4Cl. Efflux of Ca-45 from preloaded eggs was lower with ammonia activation, at 1300 cpm/ml in control seawater *vs.* 700 cpm/ml with NH_4Cl after 40 minutes.

3118. Rajendran, A., Sumitra-Vijayaraghavan, and M.V.M. Wafar. 1978. Effect of some metal ions on the photosynthesis of microplankton and nannoplankton. Indian Jour. Marine Sci. 7:99-102.

Photosynthesis in larger algae (microplankton) and smaller algae (nannoplankton) collected from Dona Paula Bay, Goa, in the East Indies, was affected after 3 hours by higher concentrations of cobalt, copper, iron, manganese, molybdenum, and zinc. Response of each group varied with metal. Copper enhanced micro- and nannoplankton photosynthesis at low levels of 8.0 and 4.0 ug/l, but decreased rates to 90% of controls in microplankton and 63% in nannoplankton in 20 ug/l. Photosynthetic rate of nannoplankton increased in up to 16 ug Zn/l, then decreased slightly in higher concentrations. Microplankton production gradually decreased as Zn levels rose to 60 ug/l. Both groups of algae showed a decreasing photosynthesis rate due to iron exposure, from 90% to 50% as concentrations rose from 4.5 to 45.0 ug Fe/l. Molybdenum increased photosynthesis at 20 ug Mo/l, and did not significantly reduce rates at higher concentrations. Manganese and cobalt, which increased photosynthetic rate slightly at low levels (8.0 ug Mn/1 or 1.0 ug Co/1), did not appear to be toxic to either size group of algae at concentrations up to 40 ug Mo/1 or 4.0 ug Co/1.

3119. Sakamoto, S. and Y. Yone. 1978. Iron deficiency symptoms of carp. Bull. Japan. Soc. Sci. Fish. 44:1157-1160.

Cyprinus carpio were fed diets with and without supplemental iron (199 mg Fe/kg diet *vs*. 10 mg Fe/kg) over a 105 day period. No significant differences were recognized between groups in: growth rate; condition factor; feed efficiency; ratio of liver, spleen and heart weight to body weight; blood serum levels of total protein, total cholesterol, total bilirubin, urea-N, glucose, calcium, inorganic phosphorus; and activities of enzymes such as glutamic oxalacetic transaminase, glutamic pyruvic transaminase, alkaline phosphatase, lactic dehydrogenase, and leucine aminopeptidase. However, in the group without the iron supplement, blood specific gravity, hemoglobin, hematocrit, mean corpuscular constants, and mean corpuscular diameter of minor length were lower; and percentage of immature erythrocytes was higher. These findings show that carp fed a diet without iron supplement manifested a hypochromic microcytic anemia.

3120. Sankaranarayanan, V.N., K.S. Purushan, and T.S.S. Rao. 1978. Concentration of some of the heavy metals in the oyster, *Crassostrea madrasensis* (Preston), from the Cochin Region. Indian Jour. Marine Sci. 7:130-131.

Concentrations of zinc, copper and iron were measured in *C. madrasensis* collected from the Cochin backwaters during 1975 and 1976. High concentrations in adult specimens, in mg/kg dry wt soft parts, of 150 to 200 for Cu, 500 to 1600 for Fe, 35 to 90 for Mn, and 7500 to 12,500 for Zn, were observed during December to May. Low values were confined to June to November, when freshwater discharge through the rivers was maximum. Metal levels in oysters were below 150 mg Cu/kg, 500 for Fe, 30 for Mn, and 4000 for Zn during this period. Juvenile oysters generally contained lower concentrations than adults. The high levels of Zn, Cu, and Fe were considered to be due to industrial and domestic pollution.

3121. Shiber, J. and E. Washburn. 1978. Lead, mercury, and certain nutrient elements in Ulva lactuca (Linnaeus) from Ras Beirut, Lebanon. Hydrobiologia 61:187-192.

Algae collected from nine locations along the coast of Ras Beirut, Lebanon, were analyzed for lead, mercury, phosphate, calcium, magnesium, iron, copper, and zinc. Low lead concentrations of 0.14 mg/kg dry wt in all samples, suggest that U. lactuca controls Pb uptake and toxicity. Phosphate levels may be a contributing factor to this process. Concentrations of all other elements seemed relatively uniform. With few exceptions, average metal levels in algae from all sites, in mg/kg dry wt, were 2.9 Hg, 100.5 Ca, 0.54 Mg, 2.7 Fe, 0.22 Cu, and 0.53 Zn. This uniformity suggests that U. lactuca is subject to similar environmental conditions and element exposure at each collecting site and that this species might be capable of maintaining biochemical stability under high levels of stress.

3122. Sivalingam, P.M. 1978. Effects of high concentration stress of trace metals on their biodeposition modes in Ulva reticulata Forskal. Japan. Jour. Phycol. 26:157-160.

Studies on algal biodeposition of Cd, Cr, Co, Pb, Zn, Mn, and Ni, at concentrations of 50, 100, 200, 300, and 500 mg/l over 48 hours, indicated that bioconcentration factors for 50 and 500 mg/l concentrations were 36 and 21X for Cd, 18 and 11X for Cr, 136 and 23X for Co, 124 and 24X for Pb, 48 and 4X for Zn, 144 and 35X for Mn, and 146 and 10X for Ni, respectively. Time course studies indicated different patterns of biodeposition for each metal, reflecting possible different physiological and biochemical interactions of these trace metals in Ulva.

3123. Spear, P.A. and P.D. Anderson. 1978. Pharmacokinetics in relation to toxicity assessment. In: Davis, J.C., G.L. Greer, and I.K. Birtwell (eds.). Proc. Fourth Annual Aquatic Toxicity Workshop, Vancouver, B.C., Nov. 8-10, 1977. Fish. Mar. Serv. Canada, Tech. Rept. No. 818:168-185.

Sunfish, Lepomis gibbosus, were exposed to ambient solutions of copper sulfate. Rate of copper accumulation in gills and LC-50 (96 hr) concentrations approximated an inverse relationship as magnitudes of the two variables changed with sunfish body weight. For rainbow trout, Salmo gairdneri, both variables were independent of body weight. LC-50 (96 hr) values for sunfish increased from 1.24 to 1.85 mg Cu/l as body wt increased, and values for trout were 0.19 to 0.21 mg Cu/l regardless of size. Accumulation rate in gills in sunfish decreased from 8.2 to 6.6 mg Cu/kg fish/hr as size increased. Accumulation rates in trout gills ranged from 1.2 to 1.6 mg Cu/kg fish/hr regardless of weight. Results are discussed in relation to metabolic rate and prediction of the tolerance of fish exposed to metal toxicants.

3124. Till, J.E. 1978. The effect of chronic exposure to ^{238}Pu (IV) citrate on the embryonic development of carp and fathead minnow eggs. Health Physics 34:333-343.

Quantitative analysis of uptake of Pu-238 citrate by carp (*Cyprinus carpio*) eggs indicated that plutonium is accumulated in egg and reaches a concentration factor of about 4 by hatching (72 hr after exposure began). Although some plutonium was concentrated on egg chorion, Pu-238 that penetrated the chorion was uniformly distributed throughout perivitelline fluid, embryo, and yolk sac. Conversion factors for eggs exposed to Pu-238 during embryological development were 2100 and 7500 rad/uCi/ml for carp and fathead minnows (*Pimephales promelas*), respectively. Eggs were exposed to Pu-238 in solution during embryogenesis. Percentage of eggs hatching, number of abnormal larvae produced, and survival of larvae were used as indicators of radiation toxicity. Concentrations in excess of 1.0 mCi/l prevented both species of eggs from hatching. Fish eggs developing in natural aquatic ecosystems contaminated with Pu-238 probably do not receive a significant dose from plutonium alpha radioactivity.

3125. Trabalka, J.R. and M.L. Frank. 1978. Trophic transfer by chironomids and distribution of plutonium-239 in simple aquatic microcosms. Health Physics 35:492-494.

Larval insects, *Chironomus riparius*, were analyzed 73 days after two additions of 0.1 uCi Pu-239/ml had been added to rearing water. Plutonium-239 concentrations were 8.2 mCi/kg wet wt in gut contents, 7.7 mCi/kg in sediment, and 0.66 uCi/l in water. Trophic transfer factors for *Chironomus* over water were 7.1 in whole animal, 0.79 in animal without gut contents, and 0.40 in animal without gut.

3126. Van Horn, W. 1975. Materials balance and technology assessment of mercury and its compounds on national and regional bases. U.S. Environ. Protect. Agen. Rept. EPA-560/3-75-007. Avail. as PB-247 000 from Nat. Tech. Inform. Serv., U.S. Dept. Commerce, Springfield, VA 22151:293 pp.

The role of mercury and its compounds in the environment and economy of the United States was studied from 164 references. A detailed material balance for mercuric compounds was developed on a national basis and for selected geographical regions, including estimates of the environmental fate of all emissions. About 80% of the almost 1900 tons of mercury used each year in the U.S. is ultimately discharged to the environment; an additional 8% is recycled, and the remainder is permanently in place. Mercury discharges enter the environment at a number of points. Of particular concern is the characteristic of mercurials to move, after discharge, from one environmental medium to another and to enter man's foodchain through various mechanisms. Present monitoring capabilities for determining Hg concentration in the environment are inadequate; therefore available data on ambient mercury levels do not provide a complete picture of either natural or elevated levels. Percent distribution of mercury discharges from man-related sources in the U.S. is: 31% to air; 6% to water; and 63% to land. About 13% of man-related discharges to water are from regulated industries, currently chlor-alkali and mercurials manufacturing. Natural sources, primarily runoff, contribute about 2X as much Hg to water as man-related discharges. Some mercury is removed from water in sewage treatment processes as sludge and is either returned to land or incinerated and returned to air. Solid wastes incorporated in regulated landfills (which currently receive about one-third of all solid wastes) do not discharge appreciable amounts of mercury to water. Most mercury discharged to water is incorporated rapidly into sediments and may be released by biological and mechanical action over a period of time. Effects of Hg have been studied with organisms in man's foodchain, including fish, molluscs, and other mammals. The author believes that the "threat to man" associated with current rates of man-related mercury discharges to the environment has not been conclusively demonstrated. Similarly, there is no conclusive evidence to indicate that a long-term buildup of mercury in the biosphere is occurring. Nonetheless, potential consequences of a mercury buildup are of such magnitude that efforts should continue to decrease the quantities of mercury discharged each year. Current and projected process technologies for mercury products were examined, and estimates of environmental losses for 1973 and 1983 presented. A set of regulatory alternatives was developed for the major technologies involving substantial losses of mercury to the environment, and economic impact of these alternatives was examined.

3127. Varanasi, U. and D.J. Gmur. 1978. Influence of water-borne and dietary calcium on uptake and retention of lead by coho salmon (Oncorhynchus kisutch). Toxicol. Appl. Pharmacol. 46:65-75.

Coho salmon in freshwater (2.6 mg Ca^{2+}/l) were exposed to sublethal concentrations (0.13 and 0.21 mg/l) of water-borne lead in the presence of increased concentrations of water-borne or dietary calcium. Uptake of lead was greatly reduced in gills, blood, liver, brain, skin, skeleton, and kidney of fish fed 8.4 mg of calcium. Lead uptake was also reduced significantly in gills, blood, skin, and skeleton of fish exposed to higher concentrations of 6.2 mg/l water-borne calcium; however, liver and kidney did not show significant reduction in lead levels compared to fish exposed to 2.6 mg Ca^{2+}/l. Bioconcentration factors were highest in gills and kidney and lowest in brain in both groups. An increased concentration of Ca in gastrointestinal tract was more effective than an increased concentration of Ca in surrounding water in reducing uptake of water-borne Pb. Retention of Pb administered via caudal vein was not significantly affected by increasing Ca concentrations in water from 2.6 to 11.9 mg/l. Increase in dietary or water-borne Ca had a less pronounced effect in reducing Pb retention in most tissues than reducing Pb uptake; nevertheless, an increase in water-borne or dietary Ca significantly reduced both uptake and retention of Pb in skin and skeleton. Turnover of Pb, and perhaps Ca, in salmon is greater in skin than in skeleton. It is concluded that, in salmonids, biological fate and, presumably, toxicity of lead is influenced by the calcium status of the fish.

3128. Waiwood, K.G., and F.W.H. Beamish. 1978. The effect of copper, hardness and pH on the growth of rainbow trout, Salmo gairdneri. Jour. Fish Biology 13:591-598.

Trout held on a fixed ration and activity regime were exposed to a number of copper (0.0 to 200.0 ug/l), pH, and hardness combinations. Growth rate, appetite, and gross conversion efficiency were determined over three consecutive 10-day exposure periods. Growth rate was most affected during the first 10 days of exposure; partial or complete recovery was observed thereafter. For a given pH, less copper was required to reduce growth by a given amount at low levels of hardness. At a given hardness, copper-induced depressions in growth rate were more pronounced and recovery slower in a low pH. No distinction could be made among total soluble or extractable copper, but predicted concentrations of six specific cupric ions varied with pH and hardness. Regression analysis indicated that only Cu^{2+} and $CuOH^{+}$ could be significantly correlated with growth rate.

3129. Weinstein, N.L., and P.D. Anderson. 1978. Lethal and sublethal toxicities of copper-nickel mixtures to the zebrafish Brachydanio reria. In: Davis, J.C., G.L. Greer, and I.K. Birtwell (eds.). Proc. Fourth Annual Aquatic Toxicity Workshop, Vancouver, B.C., Nov. 8-10, 1977. Fish. Mar. Serv. Canada, Tech. Rept. No. 818:153-167.

Zebrafish were exposed to mixtures of copper and nickel at sublethal and lethal concentrations to assess their multiple toxicities. The response variable of lethal bioassays was percentage mortality, a quantal factor, while sublethal response was graded in terms of fecundity. Lethal and sublethal mixtures evoked supra-additive effects which proved to be substantially greater in magnitude than the effects predicted according to a hypothesis of toxicant additivity. Authors propose that the apparent enhancement of potency in mixtures may be attributable to alterations in kinetics of toxicant absorption, distribution, deposition, degradation, or excretion.

3130. White, A.W. 1978. Salinity effects on growth and toxin content of Gonyaulax excavata, a marine dinoflagellate causing paralytic shellfish poisoning. Jour. Phycology 14:475-479.

The optimum salinity for growth of G. excavata from Cape Ann, Massachusetts, was 30.5 o/oo. It grew well over a range of 20 to 40 o/oo S, and tolerated salinities from 11 to 43 o/oo. Growth rates at 24 and 20 o/oo S were only 10 and 20% lower, respectively, than the maximum of 0.36 divisions/day. It is unlikely that salinity fluctuations in coastal areas where diatoms occur would significantly alter growth. The paralytic toxin content of Gonyaulax increased with increasing salinity up to 37 o/oo. Toxicity of Gonyaulax in nature may, therefore, be influenced by changes in salinity.

3131. Williams, D.R. and J.P. Giesy, Jr. 1978. Relative importance of food and water sources to cadmium uptake by Gambusia affinis (Poeciliidae). Environmental Research 16:326-332.

Relative importance of food and water as cadmium sources to mosquitofish, G. affinis, was studied in a factorially designed experiment with 0.1 and 1.0 mg Cd/kg dry wt in food and 0.00002 and 0.01 mg Cd/l in water after 2 to 8 weeks of exposure. There was significant Cd uptake from water, but no significant uptake from food, except after 8 weeks in the presence of Cd in water. Fish exposed to high Cd levels in water contained 46.9 mg Cd/kg dry wt with low Cd diet and 71.5 mg/kg with high Cd diet. When exposed to a continuous flow of 10 ug Cd/l in water, G. affinis did not reach equilibrium Cd concentration before 8 weeks.

3132. Zaba, B.N. and E.J. Harris. 1978. Accumulation and effects of trace metal ions in fish liver mitochondria. Comp. Biochem. Physiol. 61C:89-93.

Uptake and effects of calcium, copper, manganese, and zinc in liver mitochondria of the freshwater fishes Salmo gairdneri and Esox lucius, and the marine teleosts Gadus morhua and Pleuronectes platessa were studied. Ca^{2+} and Mn^{2+} were taken up by an energy-dependent process similar to that described for rat liver mitochondria. Cu^{2+}, however, was taken up by an energy-independent process which stimulated potassium uptake. Zn^{2+} was accumulated to a very limited extent. Zn^{2+} and Mn^{2+} caused very strong inhibition of respiration. Implications of these findings are discussed.

SECTION III

INDEX

Three indices to this volume are presented: INDEX-METALS, INDEX-TAXA, and INDEX-AUTHORS. Cumulative indices to the first three volumes in this series are located on pages 361 to 486 of EPA Report 600/3-78-005 (Third Annotated Bibliography on Biological Effects of Metals in Aquatic Environments).

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